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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. VIII. APRIL, 1895. NO. 1.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-THIRD YEAR, 1894-95.

THURSDAY, January 10, 1895.

THE 466th meeting of the SOCIETY OF ARTS was held at the Institute, in the Walker Building, this day at 8 P.M., Mr. George W. Blodgett in the chair.

The records of the previous meeting were read and approved. Messrs. William Brophy, of Boston, and Warren A. Rodman, of Wellesley Hills, were duly elected Associate Members of the Society.

The following paper was read by title:

"The American College as a Moral Force," by William T. Sedgwick, Ph.D.

Mr. W. S. Hadaway, Jr., of Boston, read a paper on "Electric Heating." Many new forms of apparatus were shown and described. The meeting then adjourned.

THURSDAY, February 14, 1895.

The 467th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., President Walker in the chair.

The records of the previous meeting were read and approved. Mr. Charles T. Main, of Boston, was duly elected an Associate Member of the Society.

The President then introduced Mr. Arthur A. Fuller, M.E., of the Builders' Iron Foundry, Providence, who gave an address on "Construction and Operation of Seacoast Defense Mortars and Carriages," fully illustrated with the lantern. At its close the President introduced Lieutenant-Colonel S. M. Mansfield, U. S. A., who read a paper on the "Defense of Boston Harbor." A general discussion followed the papers.

The thanks of the Society were voted to the speakers for their interesting and instructive papers, and the meeting adjourned.

THURSDAY, February 28, 1895.

The 468th meeting of the SOCIETY OF ARTS was held at the Institute, in the Walker Building, this day at 8 P.M., Professor C. R. Cross in the chair.

The records of the previous meeting were read and approved. Mr. Robert Batcheller, of Boston, was duly elected an Associate Member of the Society.

The following paper was read by title:

"An Investigation of the Principles of Solubility Effect, and a Comparison of the Values of Dissociation Calculated from them and from the Electrical Conductivity," by Arthur A. Noyes and Charles G. Abbot.

The Chairman then introduced Mr. Frederick E. Ives, of Philadelphia, who read a paper on the "Reproduction of Natural Colors by Photography," in which he gave the details of his photochromoscope system. The paper was fully illustrated with the lantern, and was followed by a general discussion.

The thanks of the Society were voted to Mr. Ives for his very interesting paper. The President then declared the meeting adjourned. After adjournment the members and their guests inspected and tried the improved stereoscopic form of the photochromoscope.

THURSDAY, March 14, 1895.

The 469th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., President Walker in the chair.

The records of the previous meeting were read and approved.

The following paper was read by title:

"Further Experiments for Determining the Fusibility of Fire-Clays," by H. O. Hofman.

Professor C. Frank Allen, of the Institute, read a paper on "Highways," which was very fully illustrated with the lantern. At its close the President declared the meeting adjourned.

THURSDAY, March 21, 1895.

The 470th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. Henry M. Howe in the chair.

The meeting being a special one, no business was transacted, and the Chairman at once introduced Professor C. F. Mabery, of Cleveland, who read a paper on the "Occurrence and Composition of the Ohio and Canadian Sulphur Petroleums." The paper was very fully illustrated with the lantern, and is published in the present number of the *Quarterly*. The Chairman extended the thanks of the Society to Professor Mabery, and declared the meeting adjourned.

THURSDAY, March 28, 1895.

The 471st meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. George W. Blodgett in the chair.

The records of the 469th meeting were read and approved. No other business coming before the Society, the Chairman introduced Professor William H. Pickering, of Cambridge, who read a paper on "Astronomical Investigations at Mountain Observatories." The paper was illustrated with the lantern.

The thanks of the Society were extended to Professor Pickering, and the meeting adjourned.

CLEMENT W. ANDREWS, *Secretary.*

COMPOSITION OF THE SULPHUR PETROLEUMS OF OHIO AND CANADA.

By CHARLES F. MABERY, Professor of Chemistry, Case School of Applied Science.

Read March 21, 1895.

Although the United States is in the front rank in the petroleum producing countries of the world, less is actually known concerning the composition of American petroleums than of the products of other fields of far less importance. This fact has especial significance since the pioneer efforts in reaching oil deposits, in which great inventive skill and adaptation of methods were early displayed, as well as the application on a large scale of methods of fractional distillation, for the separation of commercial products, were here put forth. In the sudden discovery in 1884 of immense deposits of oil in the Trenton limestone the proficiency in methods of drilling and manipulating oil and in the preparation of industrial products acquired in Pennsylvania was of great service in the new fields.

To both geologists and oil men the discovery of great quantities of oil in the Trenton limestone constituted an important epoch even in the midst of wonderful growth of the petroleum industry in other fields. Fortunately, through the intelligent efforts and extensive labors of Professor Edward Orton, State Geologist of Ohio, the Geological Survey has acquired very complete accounts of the geological formations and of the occurrence of petroleum in this territory. With the aid of persons controlling these oil fields Orton was able to demonstrate the geological formations associated with the oil-bearing limestone, the essential features of the anticlinal structure, the relations of source, reservoir, and cover in the oil deposits, and the dolomitic character of the limestone, to which is due its porosity. The existence of a definite limit to the deposits of oil and gas was early recognized and its dependence upon the salt water level, which is the cause of the high pressure to which the gas and oil are subjected.

The qualities of Ohio petroleum are as peculiar as the mode of its

occurrence. Unlike most petroleums from other fields, it contains a considerable percentage of sulphur, and in other respects it differs essentially from oils obtained from the Pennsylvania territory.

The geological features of the occurrence of petroleum in Canada have not been so thoroughly investigated as those of Ohio petroleum. The late Dr. T. Sterry Hunt was the first to call attention to the deposits of oil in the limestones, and the modes of its formation and storage in the Trenton and other limestones which he early maintained have since been verified by more extended investigation in the Ohio and Canadian fields. Outside of the Canadian geological reports various accounts have been published on the geology and technology of the Canadian oil deposits in the Township of Enniskillen, but much information has been acquired by oil men of long experience in those fields which has not been accumulated in printed reports.

Hunt early recognized the anticlinal formation in Western Ontario and its association with salt water under hydrostatic pressure in the limestone as essential features for the production of a large supply of oil. The opportunities for observation in 1863, when Hunt's conclusions were first published, were limited chiefly to the outcropping limestone formations at Manitoulin Island and the few wells that had been drilled in the productive fields in Lambton County.

Unlike the oil-bearing limestone in Ohio, the deposits at Petrolia and Oil Springs in Canada occupy, at comparatively shallow depths, the corniferous limestone far above the Trenton formation, which lies at depths of more than 2,000 feet. As in Ohio, no outcropping oil rock appears in the immediate vicinity of the oil fields, but both formations are visible at the surface in a southeasterly direction from Georgian Bay. The two oil fields in Canada are contained in parallel anticlinals approximately ten miles apart, and extending in a direction at right angles to a northeasterly direction from the oil fields in Ohio. The oil territory at Petrolia is about five miles in its greatest length and somewhat less than two miles in its average width, with an area of eight square miles. The area of productive territory at Oil Springs is two square miles. In the early days some of the Canadian wells yielded an enormous flow of oil, but at present the pressure is slight and no oil is to be obtained without pumping. At present the total number of wells is 8,000, of which 6,000 are in operation at Petrolia. The annual production is 800,000 barrels, including a monthly production at Oil Springs of 17,000 barrels. At Petrolia the average

depth of the wells is 465 feet, and at Oil Springs 380 feet. The small yield from individual wells is offset by their long life. Some wells now in operation have flowed steadily during thirty years.

Crude oil is here stored in tanks excavated to a depth of 50 or 60 feet in the Erie clay, with a diameter of 30 feet, and lined with planks to a depth of 30 feet. Each tank has a capacity of 5,000 to 10,000 barrels, and the total tankage capacity in both fields is 1,000,000 barrels. Oil is collected from the wells in wagon tanks and brought to receiving tanks, from which it is pumped to the central stations near the refineries.

Canadian oil is refined in the usual manner. Much gas is evolved, which is serviceable in heating the retorts. In the crude stills gasoline and burning oil are run off to 37° Baumé, and the residue is then transferred to the tar still, from which heavy oils are run off to 30.5° B. and the residue coked. The last distillate is again distilled and the residue coked as before. In refining much depends upon the skill of the operator. With careful treatment and use of an alkaline solution of plumbic oxide a burning oil of excellent quality is prepared. From Petrolia crude 2 per cent. of naphtha is obtained, and from Oil Springs crude, 7 per cent. The yield of burning oil from either source is 43 per cent. The quantity of tar is 30 per cent. of the crude oil, from which the yield of heavy oil is 20 per cent., with a residue of coke equivalent to 10 per cent.

The anticlinal system is well marked in the Canadian fields, the anticlinals forming low terraces in which the oil collects on the slopes near the summit, where it is held under pressure by the salt water. The variations in the oil-bearing strata have been carefully studied by Messrs. M. G. Woodward and F. J. Carman, from whom I obtained valuable information concerning this and other features of oil production in this territory. In prospecting for oil outside of the producing fields it has been shown that corniferous limestone is reached at 335 feet at Petrolia; at Sarnia, sixteen miles distant in a west-northwesterly direction, at 503 feet. East of Petrolia the strata again dip to 390 feet, and again rise where many attempts — some partially successful — have been made to discover another deposit similar to that at Petrolia.

The oil territory at Oil Springs is situated on an anticlinal parallel to that which supplies oil at Petrolia, and it has been thought very probable that this anticlinal incloses other deposits. This belief has

led to much prospecting along the direction of this anticlinal, especially in the township of Euphemia, where oil in limited quantities has been found at a distance of twenty miles from Oil Springs. Much oil has been taken from deposits in both fields, which seem to be independent of the main producing fields. These "pockets" are usually found at a less depth, and from them the great producing wells of the past have undoubtedly been obtained.

The geological formations in which sulphur petroleums are found in other regions are essentially different from those observed in Ohio and Canada. In the report for 1891 of the Geological Survey of Kentucky, Orton has shown that the oil deposits of that field present the same features of source, reservoir, and cover, with an anticlinal structure distinctly outlined. But the reservoir is here a black shale of the Devonian period, instead of the lower Silurian limestone, as in Ohio. The high sulphur oil in California is also found in a peculiar formation; it consists of a bluish slate or shale, more or less compact with a variable mixture of fine quartz sand, and the conditions of reservoir and cover which have been found essential in deposits where oil is stored under pressure seem to be wanting. The dependence of storage pressure upon the especial features of a porous reservoir and an impenetrable cover is clearly shown in Ohio, where there is scarcely a geological formation that does not contain oil. But the enormous quantities of oil contained in the shales and limestones is entirely without value since it cannot be economically collected.

The formation of petroleum has received much attention both from a chemical and a geological point of view, and the prevailing theories have been ably presented and discussed by Orton, who has presented the following summary in his report on the occurrence of petroleum in Western Kentucky:

1. Petroleum is derived from organic matter.

2. Petroleum of the Pennsylvania type is derived from organic matter of bituminous shales, and is probably of vegetable origin.

3. Petroleum of the Canada type is derived from the limestones, and is probably of animal origin.

4. Petroleum has been produced at normal rock temperatures (in American fields), and is not a product of destructive distillation of bituminous shales.

5. The stock of petroleum in the rock is already practically complete.

Notwithstanding the early suggestions that the formation of petroleum in the limestones be referred to animal remains, until the discovery of oil in the Trenton rocks geologists attributed its formation exclusively to the decomposition of vegetation. Abroad the prevailing belief seems to have been that the formation of all petroleums should be referred to the decomposition of animal remains. By some writers credence is still given to the theory of Mendelejeff that all petroleums have been and are still formed by the action of water on iron or iron carbides highly heated within the earth; but on account of a lack of proof and the serious objections urged by geologists, based upon observed facts, this explanation is not generally accepted. At present the data collected seem to be insufficient to establish any particular method of formation. Even if the theory of animal origin be accepted for the limestone oils it cannot be asserted that vegetable remains may not have been in part instrumental.

From a chemical point of view some experimental evidence has been brought to bear on the solution of this problem. In 1865 Warren and Storer subjected a lime soap, prepared from menhaden oil, to destructive distillation with the formation of a hydrocarbon naphtha, from which they separated several series of hydrocarbons identical with those which Warren had previously identified in Pennsylvania petroleum. More recently Engler submitted menhaden oil to destructive distillation under high pressure, and in the product distilled he identified the constituents ordinarily separated from natural petroleum, including naphtha, the burning oil hydrocarbons, and paraffine. The formation of such products, however, by the distillation of organic matter has long been known. Sixty years ago Reichenbach separated paraffine from the products of the distillation of both vegetable and animal matter. Nitrogen compounds were early recognized in oils distilled from bones.

Chemical Composition of Petroleum.

Although various attempts had previously been made to separate the constituents of petroleum, the first systematic examination was undertaken in 1862 by Pelouze and Cahours,[1] who identified the presence of the series of hydrocarbons C_nH_{2n+2}, beginning with butane, boiling at 0°. From their results Pelouze and Cahours as-

[1] Comptes rendus, 54, 1241; 56, 505; 57, 62.

sumed that the heavier oils and paraffine have the same composition as the hydrocarbons of lower boiling points, and as a generic term for the series Watt suggested the name paraffine hydrocarbons, by which these constituents of petroleum have since been known in chemical literature. Members of the same series were observed by Schorlemmer[1] in a product distilled from cannel coal, and in a distillation of American petroleum Schorlemmer[2] obtained other members of the series that had been overlooked by Pelouze and Cahours. C. M. Warren[3] undertook a more thorough investigation of Pennsylvania petroleum, conducting the separations in a fractional condenser which he had devised especially for such distillations. In a long course of distillations Warren separated two series of hydrocarbons, beginning with butane, with a homologous difference in boiling points for CH^2 of 30°, and with a difference in boiling points between the members of one series and the isomeric members of the other of a little less than 8°. One of the series C_nH_{2n+2} identified by Warren terminates at 127.8°, the other at 150°. The fractions of higher boiling points were found to contain members of the series C_nH_{2n}. The results of Warren indicated, in the distillates above 150°, the absence of members of the series C_nH_{2n+2}, notwithstanding the assertions of Pelouze and Cahours that distillates from these portions of petroleum have the composition homologous with marsh gas. In the earlier examinations of American petroleum by Pelouze and Cahours and by Schorlemmer it is somewhat uncertain to what extent Pennsylvania crude oil was employed and to what extent Canadian oil, since in allusions to the crude product American petroleum is mentioned, with occasional reference to Pennsylvania or to Canada as the particular source.

The presence of aromatic hydrocarbons in American petroleum was first established by Schorlemmer in 1865, who identified benzol and toluol in a distillate collected below 150° from Canadian petroleum by treating this portion of the oil with nitric acid, reducing with tin and hydrochloric acid and distilling with sodic hydrate. The oil distilled had the odor of aniline and gave the rosaniline reaction with

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[1] Journal of the Chemical Society, 1862, 419.

[2] Chemical News, 1863, 157.

[3] Memoirs of the American Academy, N. S., 9, 135; Proceedings of the American Academy, 27, 56.

bleaching powder. The distillate between 150° and 170° gave a mixture of liquid and solid nitro-products, and the solid portion was recognized as trinitrocumol. Benzol and its homologues have since been found in Pennsylvania petroleum by several chemists. Petrocene was investigated by Sadtler.[1] From American kerosene, in a portion distilling at 170°–190°, Engler[2] separated pseudocumol and mesitylene by the formation of nitro compounds, and he estimated that the quantity present in crude Pennsylvania oil is equivalent to 0.2 per cent. Engler also identified these hydrocarbons in German, Galician, Italian, and Russian petroleum; in the latter, to the extent of 0.1 per cent. After ascertaining in the petroleum of the Central Caucasus the presence of hexahydro derivatives of the aromatic series, Beilstein and Kurbatoff[3] examined American ligroin for the same hydrocarbons, but succeeded in identifying only hexahydroisoxylol. No attempts were made to ascertain the presence of the higher homologues.

Petroleum from various localities in the Caucasus has been quite thoroughly investigated by Russian chemists, and it has been found to differ in its composition very essentially from Pennsylvania oil. It is held by Mendelejeff, Engler, and others that none of the petroleums, so far as they have been examined, differ essentially with respect to their components, but that the observed variation in the qualities of different oils depends rather upon a variation in proportions. This difference in proportions, however, is so marked that in certain oils some of the constituents constitute nearly the whole body of the oil, with others present only in minute quantities in comparison with other oils, in which the former constituents are almost entirely absent, the great body of the oil consisting of substances nearly wanting in the first. The thorough investigations on the composition of the Caucasus petroleum by Markownikoff and Ogloblin[4] proved the presence in oil from Baku of benzol, toluol, isoxylol, pseudocumol, mesitylene, isodurol, durol, and higher hydrocarbons with their structure not yet determined, $C_{11}H_{14}$, $C_{11}H_{12}$, $C_{12}H_{14}$, and $C_{13}H_{14}$, with indications of the homologues of styrol and phenylacetylene. The

[1] American Chemical Journal, 1879, 30.

[2] Berichte der deutschen chemischen Gesellschaft, 18, 2234.

[3] Berichte der deutschen chemischen Gesellschaft, 1880, 2028

[4] Annales de chimie et de physique (6), 2, 372.

results of Beilstein and Kurbatoff indicate the presence in the petroleum from the Central Caucasus of members of the series C_nH_{2n+2}, with benzol and toluol, and that the oil from the coast of the Caspian Sea consists mainly of the homologues of hexahydrobenzol. In the oil from the Balakhani plain on the Apscheron Peninsula Markownikoff and Ogloblin found large quantities of the aromatic hydrocarbons; but in oil from the Central Caucasus they found naphtenes to the extent of 80 per cent. of the crude oil and the aromatic hydrocarbons to the extent of 10 per cent. At first Markownikoff looked upon the naphtenes as isomeric with the hexahydro compounds; but later Markownikoff and Spady[1] appeared to accept the identity of octonaphtene and hexahydroisoxylol. In the *Berichte* (No. 7) for April, 1895, the synthesis of 1 — 3 — dimethyl hexamethylene $C_6H_{10}(CH_3)_2$ is described by Zelinsky, and it is shown to be identical with the octonaphtene of Markownikoff or hexahydroisoxylol. Markownikoff and Ogloblin proved also the presence of hexahydromesitylene, besides other oils with the composition C_9H_{18} and the members intermediate to $C_{15}H_{30}$.

Benzol and its homologues were identified in Hanover petroleum by Bussenius and Einstuck[2] and by Ulsmann.[3] In petroleum from Boryslaw in Galicia, Lachowicz[4] found benzol, toluol, isoxylol, and mesitylene; but of the hexahydro series, only hexahydroisoxylol. Pawlewski[5] found in Galician petroleum 2 per cent. of aromatic hydrocarbons, chiefly benzol and *p*-xylol, the latter recognized for the first time in any petroleum. Naphthalene, anthracene, their homologues, and other allied hydrocarbons have been reported from various sources.

Concerning the presence of unsaturated hydrocarbons in crude petroleum there seems to be a wide difference of opinion. Some investigators have doubted the existence in crude oil of these bodies, and where they have been found in distillates it has been assumed that they have resulted from decomposition by distillation. In the lower fractions of Galician oil Lachowicz obtained no reaction with bromine

[1] Berichte der deutschen chemischen Gesellschaft, **20**, 1850.

[2] Annalen der Chemie und Pharmacie, **113**, 167.

[3] Annalen der Chemie und Pharmacie, **114**, 279.

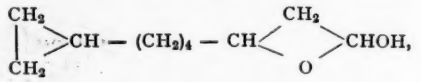
[4] Annalen der Chemie und Pharmacie, **220**, 187.

[5] Berichte der deutschen chemischen Gesellschaft, **18**, 1915.

even after long standing. Above 200° the presence of unsaturated hydrocarbons, indicated by the ready absorption of bromine, was attributed to decomposition. On the other hand, Engler states that petroleum from Elsass (Pechelbronn), Oelheim (Hanover), Tegernsee, Pennsylvania, Galicia, and Baku contains members of the series C_nH_{2n+2} and the series C_nH_{2n}, both unsaturated hydrocarbons and naphtenes. Markownikoff and Ogloblin[1] allude to the presence of unsaturated aromatic hydrocarbons in the oil from Baku.

Before the discovery by Wreden of the hexahydro-aromatic compounds Warren separated from Pennsylvania petroleum a series of hydrocarbons C_nH_{2n}, which were probably of the same series. It now seems probable that the constituents of Pennsylvania petroleum above 150°, assigned by Pelouze and Cahours to the series C_nH_{2n+2}, really belong to another series.

It has long been known that analyses of crude petroleum have shown less than 100 per cent. of carbon and hydrogen, and the deficiency has been attributed to the presence of oxygen. The first attempt to separate oxygen compounds from crude petroleum was made in 1874 by Hell and Medinger[2], who agitated crude petroleum with a solution of sodic hydrate and then added sulphuric acid in excess to the alkaline solution. The oil which separated was distilled and converted into a methyl ether; by saponification of this ether an acid was obtained to which was assigned the provisional formula $C_{11}H_{20}O_2$. Aschan[3] obtained a mixture of acids by the addition of sulphuric acid to the sodic hydrate solution used in the refining of Baku oil. One acid, $C_8H_{14}O_2$, was obtained that distilled at 237°–239°, and another, $C_9H_{16}O_2$, that distilled at 251°–253°. Aschan called the first acid octonaphtenecarboxylic acid; by distillation with hydriodic acid it was converted into hexahydroxylol. By similar methods Zaloziecki[4] separated oxygen compounds from petroleum, which were readily oxidized to acids when exposed to the air. For one of these bodies, assuming it to be a lacto-alcohol, Zaloziecki suggested the formula



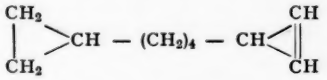
[1] Berichte der deutschen chemischen Gesellschaft, 1883, 1873.

[2] Berichte der deutschen chemischen Gesellschaft, 1874, 1216.

[3] Berichte der deutschen chemischen Gesellschaft, 1890, 8867; 1891, 1874, 2710; 1892, 3661.

[4] Berichte der deutschen chemischen Gesellschaft, 1891, 1808.

and to the hydrocarbon obtained by distillation he gave the formula



Engler asserts that the acids separated by this method are oxidation products of other constituents of the crude oil. Markownikoff and Ogloblin stated that the distillate 75°–85° from Caucasus oil contained 0.76 per cent. of oxygen compounds, and the fraction 220°–230°, 5.21 per cent. The oxygen compounds are in part acid, in part neutral, and in part phenol. The acids $C_{10}H_9COOH$ and $C_{11}H_{11}COOH$ were obtained as colorless oils.[1] Markownikoff and Ogloblin regarded these substances as naphtenecarboxylic acids. St. Clair Deville[2] showed that the percentage of oxygen in oils from different localities varies between 2.1 per cent. in the Canadian petroleums and 5.6 per cent. in the oil from Zante.

Most of the petroleums contain nitrogen, usually in minute quantities. Beilby[3] found 0.08 per cent. of nitrogen in the residuum from Pennsylvania oil and 0.37 per cent. in the coke, which corresponds to 0.008 per cent. of the crude oil; crude Russian oil gave .05 per cent. of nitrogen. In examining oils from different localities for nitrogen Peckham[4] found in petroleum from West Virginia 0.54 per cent.; in Mecca oil, 0.23 per cent.; and in California oil, from 0.56 to 1.1 per cent. In Egyptian oil Kast and Kunkler[5] found 0.3 per cent. of nitrogen, 1.21 per cent. of sulphur, and 0.2 per cent. of oxygen. Certain alkaloid bases were detected in paraffine oils by Weller,[6] and Bandrowski,[7] by agitating Galician oil during several weeks with sulphuric acid, obtained a substance containing nitrogen. This substance solidified at 20°, and it formed a platinum salt containing 19.7 per cent. of platinum. Zaloziecki[8] neutralized a sulphuric acid extract from the

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[1] Berichte der deutschen chemischen Gesellschaft, 1883, 1873.

[2] Comptes rendus, **66**, 442; **68**, 485.

[3] Journal of the Society of Chemical Industry, 1891, 120.

[4] Geological Survey of California, **2**, Appendix.

[5] Chemisches Centralblatt, 1890, 932.

[6] Berichte der deutschen chemischen Gesellschaft, 1887, 2097.

[7] Monatshefte für Chemie, 8, 224.

[8] Monatshefte für Chemie, 13, 498.

refining of a petroleum distillate with calcic hydrate and distilled with steam. The oily distillate contained nitrogen, and it formed a platosochloride whose percentage composition corresponded to that of tetrahydrocorridine

$$(C_{10}H_{19}NCl)_2\ PtCl_2,$$

or to the formula

$$(C_{10}H_{21}NCl)_2\ PtCl_2;$$

another insoluble platoso compound was obtained to which was assigned either the formula

$$(C_{10}H_{15}NCl)\ PtCl_2 \text{ or } (C_{10}H_{17}NCl)_2\ PtCl_2.$$

Soon after the discovery of the Ohio sulphur petroleum, in a technical examination of crude oil which I was called upon to make I observed that it contained an unusually large amount of sulphur. An examination of the crude oil was soon undertaken with particular reference to the sulphur compounds, and there was finally separated a homologous series of sulphides $(C_nH_{2n+1})_2S$, including methyl-, ethyl-, propyl-, butyl-, isobutyl-, pentyl-, ethylpentyl-, hexyl-, with higher distillates containing sulphur compounds not yet identified.[1] Large quantities of distillates have been collected after long distillation *in vacuo*, which proved to be mixtures of sulphur compounds, unsaturated hydrocarbons C_nH_{2n}, and apparently saturated hydrocarbons, either of the series C_nH_{2n+2} or of the series of hexahydroaromatic compounds C_nH_{2n}.

The sulphur compounds in Canadian oil have received some attention.[2] Several members of the series $(C_nH_{2n+1})_2S$ have been recognized since that publication with evidence of sulphides of another series. The separation of the sulphur compounds from the distillates is extremely tedious even after a long-continued fractional separation of the sulphur oil. The sole method available, so far as we have proceeded, includes precipitation with alcoholic mercuric chloride and decomposition with hydric sulphide in the presence of alcohol. The product is a mixture, the constituents of which must be separated by prolonged fractional distillation.

The peculiar character of the distillates was observed while studying the sulphur compounds, and as the Ohio petroleum had never been

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[1] Mabery and Smith, Proceedings of the American Academy, **24**, 218; American Chemical Journal, **16**, 83.

[2] Preliminary Examination, Mabery, American Chemical Journal, **16**, 89.

submitted to chemical examination and the Canadian oil to only partial study both products invited further attention. On account of the tendency to decomposition manifested by other constituents of the crude oils than the sulphur compounds it was evident that these bodies could not be separated by the ordinary process of distillation without such serious decomposition as to render the results of little value. When distilled in contact with the air all distillates, except the most volatile, were highly colored. Attempts were therefore made to avoid decomposition, so far as possible, by the exclusion of air and by conducting the distillations under reduced temperatures. In order, furthermore, to be sure that the distillates should represent as nearly as possible the original constituents, we started with crude oils instead of refinery distillates. In certain portions of our work connected with the separation of constituents that are present in minute quantities, requiring large quantities of material, we have used crude distillates as the starting point, but these distillates were not treated with reagents before we received them.

The distillation of considerable quantities of crude oil *in vacuo* involved certain difficulties which we were long in overcoming. Metallic stills could not be used, and glass was unsafe with large quantities of oil. Only earthenware and porcelain remained, and we have found it difficult to procure earthenware that would support a vacuum. Certain English and German stills of limited capacity have been found serviceable, but the stills which are perfectly satisfactory for such work are those manufactured in the Royal Berlin porcelain factory. One of these stills, with a capacity of fifteen liters, has been in use almost continuously during several months, and it has apparently suffered no deterioration.

In maintaining a vacuum for the continuous distillation of petroleums, especially those containing considerable quantities of sulphur compounds, rubber corks cannot be used in making connections, on account of softening action of the oil on the rubber. It is nearly impossible to select common corks sufficiently free from imperfections, but it was found that corks could be treated with a rubber lute in such a manner as to make them air-tight. This lute is best made by dissolving pure caoutchouc in very light gasoline, which readily evaporates, leaving a thin, strong film of rubber. When such a lute is applied to joints of the apparatus during the formation of a vacuum the film of rubber is drawn into the joints and pores of the corks, thus

sealing them permanently, and with an occasional application of the lute there is no difficulty in maintaining any desired vacuum.

In prolonged distillation it is important to regulate the tension so that it shall be constant during the collection of all distillates. For this purpose a special form of regulator was devised, depending upon the introduction of air away from the still, through a glass stopcock, by means of a long lever. By this means it has been found possible to control the vacuum at any desired point with very little attention. The difference in boiling points in vacuum distillation varies between 60°–65° for the lower constituents and 100°–125° for portions distilling at 300°–350°. Vacuum distillation prevents serious decomposition even of the highest distillates. We have carried the temperature to 375°, and this is as far as distillation is possible with ordinary connections. The residue above this point is a thick oil, apparently undecomposed; cracking is easily observed, since it immediately destroys the vacuum. For further distillation of this residual oil an apparatus must be devised to avoid the use of any connections other than glass or porcelain.

In a general examination of these petroleums with reference to specific gravity, bromine absorption, proportions that distil at different temperatures, specific gravity of the distillates and their bromine absorption, it is found that the Ohio oil stands between the Pennsylvania and Caucasus oils, and the Canada oil is between the Ohio and Caucasus. Below 120° 19.7 per cent. of Pennsylvania oil distils, 0.5 per cent. of Caucasus; below 110° 9.75 per cent. of Ohio oil; and below 115° 2.75 per cent. of Canada oil. Above 320° the residue in Pennsylvania oil is equivalent to 35.54 per cent.; in Caucasus oil, to 53 per cent.; in Ohio oil above 350°, to 43 per cent.; and in Canadian oil, to 70.75 per cent.

The crude Ohio and Canadian oils are so unstable that decomposition can only be prevented by distillation *in vacuo*, with exclusion of air and corresponding reduction in temperature. After the first distillations it is possible to continue under atmosphere pressure. Separation of the constituents of such complex mixtures as petroleum by fractional distillation — the only method possible — is exceedingly tedious. Of the various appliances that have been proposed as an aid in such separations, the worm condenser devised by Warren and the bead column by Hempel are probably the most convenient and efficient. Certainly no form of apparatus approaches the Warren con-

denser in the rapid separation of the constituents of petroleum that require freezing mixtures.

From the most volatile refinery distillate portions were collected, after many distillations, that distilled constant at 0° and 8°–9°. The former was undoubtedly butane, and the latter distillate from both Ohio and Canada oil was shown by vapor density determinations to have the composition required for butane. A study of these fractions is now in progress with large quantities of the oils for the purpose of ascertaining their identity. Between 29° and 30° a distillate collected that gave a value in a determination of its vapor density required for isopentane, and another collecting at 37°–38° the value required for pentane.

A product collected at 60°–61° that distilled tolerably constant within this limit, and its vapor density corresponded to that required for isohexane. The portion collected at 67°–68°, the boiling point of normal hexane, also gave as its vapor density a value required for this hydrocarbon.

In identifying the higher homologues 41.5 kilos of crude Findlay oil was distilled *in vacuo* under a tension of 50 mm. and the portions collected below 150° were subjected to prolonged fractional separation, with the aid of Hempel columns and Warren condensers, until the fractions collected, for the most part, within limits of one degree of boiling point of hydrocarbons that were separated by Warren from Pennsylvania petroleum. Each fraction was carefully purified by agitation with alcoholic mercuric chloride, prolonged boiling with nitric and sulphuric acids, and boiling over sodium. In this manner a distillate was obtained at 89°–90° whose vapor density corresponded to that of isoheptane, and another at 96°–97°, with a vapor density that showed it to be normal heptane.

Other members of the series C_nH_{2n+2} were recognized by their boiling points and vapor densities; for example, octane at 118°–119°, and another octane at 127°–128°, and also a nonane at 150°–151°.

Of the aromatic hydrocarbons, benzol-, toluol-, meta-, and para-xylols were found, although in very small proportions. The only representative of the hexahydro- or C_nH_{2n} series found was hexahydro-isoxylol, although hexahydrobenzol and hexahydrotoluol were carefully looked for in the portions where they should appear. The presence of higher members of this series will be determined later.

Crude petroleum from Oil Springs and from Petrolia in Canada

was subjected to a similar examination as the Ohio oil, including specific gravity, bromine absorption, percentage of sulphur, and percentages of carbon, hydrogen, and nitrogen. In respect to specific gravity, percentage of sulphur, and the proportions of distillates at the same temperatures essential differences appear in petroleum from the two Canadian fields, and each differs from oil collected in the Lima or the Findlay field in Ohio.

To avoid decomposition vacuum distillation was applied to the Canadian oils, and was found even more necessary than with Ohio oil. The distillates were purified and the same determinations made, with similar results as regards the individual constituents as has already been described in connection with Ohio products. The same butanes, pentanes, hexanes, heptanes, octanes, and the same nonane were recognized. The same representatives of the aromatic series, both of the series C_nH_{2n-6} and of the series C_nH_{2n}, were found; but benzol and its homologues were found to be present in much smaller quantity than in the Ohio oil. With the aid of my assistants and associates I am at present engaged in the study of the butanes, octanes, and distillates above 150° in the Ohio and Pennsylvania oils, the nitrogen compounds, and the oxygen compounds. Of the portions with high boiling points, distillation *in vacuo* has been carried to 375° under 50 mm., which is the limit with ordinary connections. This temperature corresponds to about 500° under atmospheric pressure. With a special form of apparatus to be constructed, it is intended to carry the distillation to 500° under 50 mm. pressure. This work is carried on with aid granted by the American Academy of Arts and Sciences from the C. M. Warren fund for chemical research.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

II. STEAM AND HYDRAULICS.

Ejector Tests.

These tests were made on a No. 6 Hancock ejector, with $\frac{3}{8}''$ diameter steam orifice and $2''$ delivery pipe. The ejector was arranged so that the lift could be varied. By means of a throttle valve in the delivery pipe the discharge pressure could be changed when desired. The steam used was found by calculating the flow through an orifice placed in the steam pipe about 2 feet from the ejector (described in in *Technology Quarterly*, 5, 358). The quantity of water delivered was found either by flowing it over an $8''$ weir or by direct weighing. The duty (foot-pounds of work done per 1,000,000 British Thermal Units used) was calculated, assuming that the heat put into the delivery water was not wasted. The heat used per pound of steam was taken as the total heat of the steam less the heat of the liquid at the delivery temperature.

Pulsometer Tests.

These tests were made on a No. 4 pulsometer, made by the Pulsometer Steam Pump Co., of New York. Water was drawn from a cistern about 8 feet below the pump. The discharge was carried up about 8 feet through a $2\frac{1}{2}''$ pipe, and the different delivery pressures were obtained by throttling the discharge. The delivery was measured by calculating the flow over a $12''$ weir. The steam used by the pulsometer was supplied through an orifice in the pipe, and the weight calculated by Napier's formulæ. On account of the throttling at the orifice the steam was superheated in some of the tests. The number of pulses was obtained by a ratchet counter, operated through a rubber diaphragm connected with the delivery in such a way that each time the ball or steam valve shifted the rubber diaphragm gave motion to

the pawl running the counter. The heat supplied per pound of steam used was taken as the total heat in the steam, minus the heat of the liquid corresponding to the delivery temperature.

Tests on a 16″, 10½″ × 12″ Duplex Blake Pump.

This pump lifted water about 8 feet through about 15 feet of 8″ pipe and discharged into a 7″ pipe. When these tests were made there was no air chamber on the suction pipe. To avoid pounding, an air cock, with an opening ⅛″ in diameter, was tapped into the suction pipe close to the pump and left open in some of the tests. The water pumped was measured in two ways: First, by calculating the flow through two 1⅛″ diameter and one 2″ diameter hose nozzles; and, second, by running the water from the hose nozzles over a 4-foot weir without end contractions.

A float in the suction tank gave the distance below a certain reference point on the air chamber of the pump; a scale and water glass on the air chamber gave the level in the chamber above this reference point; and a steam gauge on the top of the air chamber gave the delivery pressure. From these the total lift was calculated. The steam used was condensed in a surface condenser and weighed.

Six indicators were used in taking diagrams — four on the two steam cylinders, and one on the steam end of each water cylinder. In calculating the duty (or foot-pounds of work done per 1,000,000 B. T. U.) it was assumed that the condensed steam could be returned to the boilers at 212° F.

Flow of Steam Tests.

The orifice used was ¼″ diameter, 2½″ long. The entrance side of the orifice was rounded with a curve of ¼″ radius. The steam after passing through the orifice was condensed in a surface condenser and weighed. The pressure in the orifice was obtained by means of a pipe which led through the back head of the apparatus and connected with a hole $\frac{1}{64}$″ diameter drilled into the orifice at right angles to the steam jet flowing through.

The quality of the entering steam was found by using the apparatus as a throttling calorimeter. The throttling was done at the orifice, and the temperature and pressure of the superheated steam were taken beyond the orifice.

Tests on Horizontal Belt Machine.

This machine consisted of three shafts and a brake. Two of these shafts were movable, so that the tension on the test belts could be varied. From a movable driving shaft a belt led to a weighing shaft, and from this weighing shaft another belt led to a fixed shaft which was belted to a brake by a 10″ double belt. The hangers of the weighing shaft were fastened to a frame which turned on pivots vertically under the shaft. The pull of the two belts tending to turn this shaft about the pivots was weighed by two sets of scale levers. Each set of levers was attached to one of the horizontal adjusting screws of a hanger. The whole frame, carrying the weighing shaft and scales, could be moved horizontally by screws. From the weights on the scales the sum of the tensions, or $T_1 + T_2$, of each belt was calculated. From the speeds of the belts and the horse power transmitted the effective pull, or $T_1 - T_2$, of each belt was calculated, and hence T_1 and T_2 for each belt. The coefficient of friction f was calculated from the formulæ

$$\frac{T_1}{T_2} = \overline{2.718}^{f \times 3.1416}.$$

The pulleys were all about 30″ in diameter. The greatest error in reading the revolutions of the different shafts was not greater than 1 revolution in 10,000 revolutions. It was found that in the case of leather belts the moisture in the air affected the amount of slip.

Tests on a No. 7 Mack Injector.

The steam used was calculated from the flow through an orifice inserted in the steam pipe. The water delivered was weighed. The injector was fed from a tank 6 feet in diameter and 10 feet tall on the floor below. The level in this tank could be varied, but was kept constant throughout any test.

Tests on a Hancock Inspirator.

The inspirator tested had a $\frac{3}{4}$″ suction pipe and a $\frac{3}{4}$″ delivery pipe, and was supplied with steam through a $\frac{1}{2}$″ pipe. The inspirator was placed on the second floor and drew from a standpipe 26 feet long. The level of the water in this pipe was kept constant by feeding water

into it from a barrel on the second floor as fast as the inspirator took it out. By means of an electrical attachment a bell was rung whenever 100 pounds of water had been fed out of this barrel. The water delivered was also weighed, and the excess over 100 gave the amount of steam used in feeding 100 pounds.

Thermometer cups were inserted in and gauges attached to the suction, intermediate chamber, and delivery, and from these the amounts by temperatures were calculated. By "lifter first" is meant that the amount of steam used in the lifter part of the inspirator was calculated from the temperature of the suction and intermediate chamber, and that the difference between the total steam and this quantity was the amount used in the forcer.

Tests on a Wheeler Condenser.

The maker's rating of this condenser is 50 H. P. The steam surface was taken as the outside area of the large tubes in contact with steam. The water surface was taken as the inside area of these tubes. The condensing water used and the steam condensed were weighed. In some of the tests the entering steam was slightly superheated.

Boiler Tests.

In all of the tests lasting from ten to twelve hours fires were drawn at the beginning and at the end. In the tests fifty-six to one hundred and twenty-eight hours long fires were not drawn, but as near as could be judged the same amount of coal was on the grate and in the same condition at the end as at starting.

Both at the beginning and at the end of the tests when the fires were drawn the boilers were making steam at the working pressure. The water level was made the same at the end as at the beginning. All water entering the boiler was weighed in barrels and discharged into a reserve tank from which the feed pumps drew. Temperatures of the feed water were taken at frequent intervals. Coal was weighed as fired. Calorimeter readings to determine the amount of priming in the steam were taken every thirty minutes. The velocity of the air entering the ash-pit doors was obtained from readings of an anemometer placed in a galvanized iron pipe about 18″ in diameter, supplying air to a galvanized iron box fitted into the ash-pit door openings.

Tests Nos. 31 to 36 and Nos. 37 to 42 were made with some of the tubes plugged at both ends with cast-iron washers. The two bottom rows and the tubes nearest the shell were the ones plugged.

Boiler No. 4 (old numbering, No. 2 new numbering) is a 60″ horizontal multitubular boiler 17 feet long, having (70) $3\frac{1}{2}$″ tubes 16 feet long. The heating surface in the tubes = 953 square feet; heating surface in one half of the shell = 127 square feet; total, 1,080 square feet. Grate surface, 29.17 square feet. Boiler was built by E. Hodge & Co., of East Boston.

The shop boiler at the Technology workshops, on Garrison Street, is a 54″ boiler 17 feet long, having (60) $3\frac{1}{2}$″ tubes 16 feet long. The heating surface in the tubes = 817 square feet; the heating surface in one half of shell = 113 square feet; total heating surface = 930 square feet. Grate area, 25 square feet, reduced to 13.5 square feet during tests. Boiler was built by Whittier Machine Co., of Boston.

Boilers Nos. 1 and 3 (old and new numbering) are Babcock & Wilcox water tube boilers, rated at 208 H. P. each. The grate of each is 84″ × 88″, giving 51.3 square feet area. The heating surface of each is 2,214 square feet, made up as follows:

108 tubes 4″ diameter, 17′ — 8″ long outside area . . .	1,997.3	square feet.
12 tubes 4″ diameter, 4′ — 6″ long outside area	56.5	square feet.
2 drums 3 feet diameter, 17 feet long ½ outside area . . .	160.2	square feet.
Total	2,214.0	square feet.

The chimneys of Boilers 1 and 3 are 3′ × 3′ and 100 feet in height.

Test on a No. 6 Douglas Hydraulic Ram.

The ram tested had a $2\frac{1}{2}$″ drivepipe and a $1\frac{1}{4}$″ delivery. The discharge pressure was varied by means of a lever safety valve at the end of the delivery pipe. The water delivered was weighed. The overflow was either weighed directly or the weight calculated from the flow through a rounded mouthpiece of which the diameter and the coefficients for different heads were known.

TESTS ON EJECTOR AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

No. of test.	Date.	Steam pressure at ejector. (By gauge.)	Steam used per hour. (Pounds.)	Water pumped per hour, including steam. (Pounds.)	Temperature of suction. °C.	Total lift. (Feet.)	Work done by ejector. (Foot-pounds.)	Heat given up by steam. (B. T. U.)	Efficiency. (Per cent.)	Duty. (Foot-pounds per 1,000,000 B. T. U.)
	1893.									
1	Nov. 28	69.9	593.5	21,320	28.8	....	.....	.....	....	.....
2	Nov. 29	60.8	487	19,400	25.8	27.1	516,100	537,700	.12	959,800
3	Nov. 30	58.8	480	19,300	28.5	26.7	506,900	596,000	.11	963,600
4	Nov. 30	45.1	400	18,400	30.5	25.3	457,200	.....	....	1,031,000
5	Dec. 1	46.3	403	18,400	29 8	26.3	469,800	441,300	.14	1,064,000
6	Dec. 2	41.2	365	14,130	29.1	26.1	363,200	397,400	.12	935,000
7	Dec. 2	33.8	347	13,030	32 2	...	278,500	332,800	.10	836,000
8	Dec. 5	27.1	272	13,190	29.0	18.2	235,100	296,100	.10	794,000
9	Dec. 5	60.2	468	18,720	30.3	34.2	633,800	509,900	.16	1,243,000
10	Dec. 6	72.1	559	20,960	29.9	19.2	394,900	612,100	.08	645,000
11	Dec. 7	71.1	538	21,900	30.5	20.3	436,700	590,000	.10	740,000
12	Dec. 7	56.6	453	25,450	17.6	21.0	527,600	508,800	.11	1,037,000
13	Dec. 8	50.4	416	21,310	26.6	21.0	440,200	460,300	.12	956,000
14	Dec. 9	55 2	438	26,610	30.0	18.5	486,500	482,400	.13	1,009,000
15	Dec. 9	49.8	406	26,500	33.2	19.1	500,100	444,800	.14	1,126,000
16	Dec. 12	48.9	404	26,950	28 4	17.4	463,700	446,300	.12	1,040,000
17	Dec. 12	23.9	274	13,500	29.7	8.3	110,900	295,600	.01	375,000
18	Dec. 13	37.7	334	16,620	27.3	14.8	244,200	365,700	.09	668,000
19	Dec. 14	50.9	411	20,200	28.1	23.1	463,200	451,200	.13	1,027,000
20	Dec. 14	40.9	348	9,110	9.0	23.0	207,800	386,800	.07	537,000
21	Dec. 15	51.6	417	28,040	20.1	20.2	562,000	467,100	.15	1,203,000
22	Dec. 15	71.6	538	30,060	27.7	10.4	309,500	595,900	.06	519,000
23	Dec. 16	71.0	536	27,640	30.7	18.2	496,200	589,900	.11	841,000
24	Dec. 19	58.4	463	28,330	27.9	22.9	644,400	512,100	.16	1,258,000
25	Dec. 19	55 2	437	26,840	23.1	22.6	601,800	487,000	.16	1,236,000
26	Dec. 20	72.5	542	30,040	27.7	14.2	422,500	601,500	.09	702,000
27	Dec. 21	50.1	392	27,140	26.6	15.0	405,200	433,800	.12	934,000
28	Dec. 27	54.2	430	25,590	24.7	18.7	472,500	478,000	.13	988,800
29	Dec. 28	71.0	534	28,290	27.9	16.9	473,900	591,700	.10	801,000
	1894.									
30	March 15	....	559	19,650	22.9	20.9	398,300	666,200	.08	636,000
31	March 15	....	558	19,730	20.3	28.0	540,100	618,600	.11	873,000
32	March 16	.. .	559	19,290	21.8	28.0	531,800	619,500	.11	858,000
33	March 16	....	566	18,730	26.3	22.9	419,900	620,200	.09	677,000
34	March 19	....	491	16,600	29.6	22.1	356,800	524,900	.09	679,000
35	March 19	....	486	17,900	25.5	23.2	405,800	516,300	.10	786,000
36	March 20	....	483	20,620	23.3	23.2	468,900	533,900	.11	878,000
37	March 20	....	489	20,960	25.0	22.4	460,700	539,300	.11	854,000
38	March 26	....	396	20,920	26.7	22.6	464,600	439,100	.14	1,058,000
39	March 27	....	397	22,010	27.4	21.5	466,200	440,700	.14	1,007,000
40	March 27	....	401	21,170	29.6	21.9	456,200	443,400	.13	1,029,000
41	March 29	....	435	19,070	22.0	20.4	380,900	485,600	.10	784,000
42	March 30	....	365	18,370	26.0	22.6	409,000	405,300	.13	1,009,000
43	March 30	....	322	16,380	27.2	18.8	301,800	355,400	.11	849,000
44	April 2	....	383	20,030	26.6	23.3	459,000	428,400	.14	1,071,000
45	April 2	....	403	17,560	28.1	22.5	386,300	463,900	.11	869,000
46	April 3	....	265	8,140	25.8	19.4	153,300	290,100	.07	528,000
47	April 3	....	569	16,500	28.1	31.0	501,000	564,400	.10	805,000
48	April 5	....	319	15,960	28.0	22.0	353,900	352,000	.13	1,006,000

TESTS ON PULSOMETER AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

No. of test.	Date.	No. of pulses per minute.	Steam pressure at pulsometer. (Gauge.)	Steam used per hour. (Pounds.)	Water pumped, including steam. (Per hour.)	Temperature of suction. °C.	Total lift. (Feet.)	Work done by pulsometer. (Foot-pounds.)	Total heat given by steam. (B. T. U.)	Efficiency. (Per cent.)	Duty. (Foot-pounds per 1,000,000 B. T. U.)	Capacity. (Gallons per minute.)
	1891.											
1	Nov. 30	83.0	70.6	271.9	52,313	22.7	23.9	1,245,000	307,300	.52	4,053,000	104.7
2	Nov. 30	81.0	41.5	297.2	51,153	24.1	25.6	1,307,000	332,900	.50	3,925,000	102.3
3	Dec. 1	66.9	90.3	215.5	43,212	24.0	21.6	933,000	244,600	.49	3,817,000	86.5
4	Dec. 2	79.6	72.6	239.2	47,670	26.0	24.5	1,163,000	269,400	.56	4,317,000	95.4
5	Dec. 2	62.9	89.0	213.3	39,510	27.1	22.8	899,400	240,600	.48	3,738,000	79.1
6	Dec. 3	59.1	41.3	185.7	35,210	22.8	21.4	751,500	208,600	.46	3,603,000	70.1
7	Dec. 4	46.1	49.8	116.3	23,100	22.0	18.9	435,300	187,100	.30	2,326,000	45.9
8	Dec. 4	80.2	36.2	262 9	49,860	24.1	24.9	123,100	293,900	.54	4,210,000	99.2
9	Dec. 7	54.4	82.2	238.8	31,800	29.3	25.8	816,900	267,600	.39	3,053,000	63.2
10	Dec. 7	49.0	42.2	300.5	20,660	31.1	49.1	1,013,000	330,400	.39	3,065,000	40.7
11	Dec. 9	94.3	67.1	280.5	19,830	25.1	47.9	946,600	313,200	.39	3,023,000	39.1
12	Dec. 9	28.0	67.9	281.7	5,350	27.3	122.8	654,300	304,300	.28	2,150,000	10.7
13	Dec. 10	31.4	50.3	300.1	7,990	25.4	92.1	732,600	329,800	.29	2,221,000	15.4
14	Dec. 11	30.9	51.1	298.5	9,320	27.0	95.0	881,700	326,000	.35	2,705,000	18.0
15	Dec. 11	37.3	46.8	299 7	13,540	29.1	75.6	1,020,500	328,700	.40	3,105,000	26.5
16	Dec. 14	48.0	42.8	296.9	31,000	28.1	50.2	1,555,000	329,300	.61	4,722,000	61.4
17	Dec. 15	40.0	15.6	138.6	22,680	23.6	27.3	617,800	153,700	.52	4,020,000	45.1
18	Dec. 16	45.0	23.2	188.3	25,650	26.9	31.0	770,100	208,300	.48	3,698,000	51.0
19	Dec. 16	37.0	62.6	287.9	33,120	27.0	31.0	1,006,000	322,000	.40	3,124,000	64.6
20	Dec. 18	55.7	49.4	296 9	33,850	23.6	34.7	1,171,000	343,200	.44	3,413,000	67.1
21	Dec. 18	51.9	49.6	298.3	38,950	21.7	42.5	1,650,600	335,400	.63	4,943,000	77.3
22	Dec. 21	50.7	48.3	297.0	35,300	25.5	39.5	1,389,500	331,800	.54	4,188,000	70.0
23	Dec. 21	52.2	48 1	297.0	44,480	26.8	38.7	1,715,600	331,600	.67	5,173,000	88.4
24	Dec. 22	42.4	49.7	298.0	28,930	27.9	61.4	1,773,300	331,100	.69	5,356,000	57.3
25	Dec. 23	43.7	48.8	297.0	30,070	29.1	57.0	1,710,200	329,400	.67	5,192,000	59.6
26	Dec. 23	48.1	48.1	298.0	34,420	29.1	49.8	1,710,400	330,900	.66	5,169,000	68.3
27	Dec. 24	52.1	47.8	298.0	37,330	29.0	40.6	1,511,100	331,100	.59	4,564,000	74.1
	1892.											
28	Nov. 28	53.0	14.6	248.0	25,309	31.2	34.6	868,800	271,200	.41	3,203,000	50.6
29	Nov. 28	58.4	18.8	265.9	32,020	33.5	25.7	852,110	290,200	.38	2,936,000	64.0
30	Nov. 29	44 3	36.1	252.0	18,410	33.2	35.3	648,000	275,600	.30	2,351,000	36.8
31	Nov. 30	40.4	20.0	261.8	16,160	32.4	35.7	573,500	285,300	.25	2,010,000	32.3
32	Nov. 30	48.0	24.9	248.0	25,510	33.5	39.3	997,600	272,800	.47	3,657,000	51.0
33	Dec. 1	49.3	21.9	259.8	24,130	32.3	33.1	822,200	274,600	.38	2,994,000	48.3
34	Dec. 2	47.9	26.8	260.5	21,330	33.3	36.9	784,200	285,400	.28	2,182,000	42.7
35	Dec. 2	48.2	27.0	268.7	22,040	37.6	37.0	811,700	291,400	.36	2,785,000	44.1
36	Dec. 5	46.3	27.3	267.6	22,150	31.1	36.2	799,100	293,400	.35	2,724,000	44.3
37	Dec. 5	47.7	26.8	274.0	23,990	35.8	37.2	906,500	298,500	.39	3,037,000	48.0
38	Dec. 6	47.1	50.9	268.0	17,800	31.8	37.9	671,400	295,200	.29	2,274,000	35.6
39	Dec. 7	47.0	22.4	228 5	23,000	34.0	33.0	757,500	250,700	.39	3,022,000	46.0
40	Dec. 7	58.4	17.6	258.2	31,930	28.1	26.1	828,900	285,000	.37	2,908,000	64.0
41	Dec. 8	30.0	28.9	206.7	14,420	30.6	64.4	926,200	226,900	.52	4,082,000	28.9
42	Dec. 9	29.3	27.2	203.5	12,210	32.9	61.1	829,800	221,500	.48	3,747,000	24.4
43	Dec. 12	39.0	25.3	247.1	9,330	29.7	57.3	287,700	207,800	.14	1,074,000	18.6
44	Dec. 12	38.0	25 2	268.9	7,850	33.9	56.3	439,500	605,100	.09	7,264,000	15.7
45	Dec. 13	39.0	26 3	268.9	8,480	30.1	56 5	476,500	287,700	.21	1,656,000	16.9
46	Dec. 14	43.7	19.6	228.7	13,390	33.1	41.6	568,400	248,100	.30	2,345,000	25.8
47	Dec. 14	45.0	20.8	230.7	14,720	20.5	44.4	651,700	255,900	.33	2,547,000	29.5
48	Dec. 15	43.0	18.5	225.9	11,740	26.9	34.4	401,500	310,600	.17	1,293,000	23.5
49	Dec. 16	54.5	18.0	269.8	18,300	34.7	17.2	312,500	292,200	.14	1,070,000	36.6
50	Dec. 16	52.1	17.4	268.5	15,300	38.8	16.5	250,200	288,200	.11	868,000	30.6
51	Dec. 19	54 6	18.3	268.0	21,200	31 5	19.5	410,000	292,000	.18	1,404,000	42.4
52	Dec. 20	54.8	17.2	266.3	21,680	30.2	18.9	384,900	291,100	.17	1,322,000	43.4
53	Dec. 20	47.4	14.5	222.5	23,180	28.8	20 6	485,500	241,300	.25	2,012,000	46.4
54	Dec. 21	30.8	11.7	192.8	16,350	28.7	18.0	292,900	211,000	.18	1,389,000	32.7
55	Dec. 21	52.0	18.5	266.1	21,310	...	22.2	470,900	290,500	.21	1,621,000	42.6
56	Dec. 22	46.6	22.4	261.3	17,830	22.9	35.9	637 900	228,900	.28	2,208,000	35.7
57	Dec. 23	47.8	17.8	238.4	25,600	23.7	20.5	518,300	264,000	.25	1,963,000	51.2
58	Dec. 23	43.3	23.6	252.9	10,810	28.1	44.9	482,700	275,400	.22	1,753,000	21.6
59	Dec. 27	35.6	21.3	241.9	5,770	27.8	47.4	271,200	259,900	.13	1,044,000	11.6
60	Dec. 28	34.5	24.8	268.4	5,870	27.0	51.4	289,100	288,000	.13	1,004,000	11.7
61	Dec. 28	40.0	23.1	268.7	9,130	33.5	45.2	409,700	288,700	.18	1,419,000	18.3

TESTS ON PULSOMETER AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY. — *Continued.*

No. of test.	Date.	No. of pulses per minute.	Steam pressure at pulsometer. (Gauge.)	Steam used per hour. (Pounds.)	Water pumped per hour, including steam.	Temperature of suction. °C.	Total lift. (Feet.)	Work done by pulsometer. (Foot-pounds.)	Total heat given up by steam. (B. T. U.)	Efficiency. (Per cent.)	Duty. (Foot-pounds per 1,000,000 B. T. U.)	Capacity. (Gallons per minute.)
	1893.											
62	Sept. 28	47.3	18.7	240.7	25,080	26.9	36.6	915,200	265,300	.44	3,450,000	49.7
63	Oct. 2	31.7	19.9	263.8	36,760	26.2	28.1	1,031,000	302,700	.44	3,407,000	73.0
64	Oct. 4	60.9	17.3	270.5	32,550	32.5	24.0	777,800	295,500	.34	2,632,000	64.6
65	Oct. 4	69.5	18.7	270.2	44,900	36.4	30.9	1,386,000	294,200	.61	4,713,000	89.3
66	Oct. 5	68.5	19.2	270.6	46,510	34.0	32.1	1,488,000	295,900	.65	5,030,000	92.5
67	Oct. 6	41.3	33.7	271.1	26,160	25.9	73.0	1,906,000	300,100	.82	6,353,000	51.7
68	Oct. 9	60.0	17.7	278.4	30,290	31.9	24.7	745,000	304,200	.32	2,448,000	60.1
69	Oct. 9	31.1	30.9	273.3	14,970	33.4	66.0	985,000	296,200	.43	3,325,000	29.4
70	Oct. 11	29.2	20.2	269.7	35,210	30.7	35.2	1,239,000	296,200	.54	4,182,000	69.9
71	Oct. 11	14.7	34.9	269.9	9,680	32.0	81.5	785,500	292,400	.35	2,686,000	18.8
72	Oct. 12	30.0	36.4	275.0	9,270	30.7	82.5	761,300	298,600	.33	2,549,000	18.0
73	Oct. 16	29.7	37.5	270.2	8,340	29.1	86.5	718,200	293,800	.31	2,445,000	16.1
74	Oct. 18	49.3	22.7	271.7	27,610	29.8	41.8	1,152,000	298,600	.50	3,859,000	54.7
75	Oct. 18	46.5	23.7	275.8	23,760	33.0	44.4	1,052,000	301,100	.45	3,492,000	47.0
76	Oct. 19	45.5	23.2	271.6	23,350	31.8	44.1	1,026,000	297,100	.44	3,453,000	46.2
77	Oct. 20	65.5	18.1	265.2	40,220	30 2	29.0	1,162,000	291,400	.51	3,986,000	79.9
78	Oct. 23	39.2	23.8	271.4	19,310	29.1	48.6	936,100	297,600	.40	3,146,000	38.1
79	Oct. 24	34.3	28.9	272.6	13,970	28.6	62.2	866,100	298,400	.37	2,902,000	27.4
80	Oct. 25	34.9	30.1	298.9	10,870	32.8	63.8	691,300	323,600	.28	2,136,000	21.2
81	Oct. 25	49.6	27.4	288.5	22,620	37.6	47.3	1,067,000	312,200	.44	3,419,000	44.7
82	Oct. 26	73.0	28.6	391.8	44,250	29.3	29.7	1,311,000	432,100	.39	3,033,000	87.8
83	Oct. 27	64.4	28.8	385.6	36,060	35.1	34.6	1,243,000	421,000	.38	2,951,000	71.4
84	Oct. 31	74.2	28.2	384.4	47,060	30.1	32.1	1,503,000	423,400	.46	3,550,000	93.4
85	Nov. 1	20.5	29.9	178.0	6,570	27.9	71.4	467,000	194,500	.31	2,401,000	12.8
86	Nov. 1	20.0	28.3	138.2	6,040	31.7	65.9	396,600	149,600	.34	2,651,000	11.8
87	Nov. 3	75.5	39.4	524.1	47,020	31.4	33.1	1,551,000	575,500	.35	2,695,000	93.0
88	Nov. 6	76.5	39.3	519.7	49,930	31.3	33.2	1,651,000	571,400	.37	2,889,000	98.9
89	Nov. 6	45.3	37.7	431.1	19,050	36.9	59.6	1,131,000	465,400	.31	2,431,000	37.3
90	Nov. 7	43.1	38.9	372.4	22,380	27.9	68.5	1,530,000	409,300	.48	3,739,000	44.0
91	Nov. 8	58.2	38.2	469.5	33,890	33.7	47.4	1,602,000	513,800	.40	3,118,000	66.9
92	Nov. 9	56.7	39.0	481.8	36,360	28.1	49.3	1,786,000	528,300	.43	3,355,000	71.8
93	Nov. 10	45.7	38.0	392.0	26,080	28.8	66.3	1,724,000	431,800	.51	3,993,000	51.4
94	Nov. 10	48.1	37.8	417.9	28,410	34 1	55.9	1,585,000	456,100	.45	3,474,000	56.0
95	Nov. 13	31.0	39.6	272.1	14,040	26 4	84.8	1,188,000	299,600	.51	3,967,000	27 0
96	Nov. 13	36.5	40.1	366.6	18,260	29.1	76.5	1,393,000	402,300	.45	3,462,000	35.8
97	Nov. 14	68.9	21.8	314.1	44,230	33.6	29.7	1,308,000	343,700	.49	3,806,000	87.9
98	Nov. 15	68.8	20.8	302.4	43,250	33.1	29.1	1,254,000	330,900	.49	3,789,000	85.9
99	Nov. 15	24.0	21.5	168.1	12,040	17.4	52.5	630,000	187,500	.43	3,360,000	23.8
100	Nov. 16	49.5	20.6	261.2	30,170	24.5	39.0	1,175,000	289,500	.52	4,057,000	59.9
101	Nov. 17	54.0	29.9	371.2	34,180	27.3	43.9	1,498,000	410,200	.47	3,652,000	67.7
102	Nov. 20	55.3	30.4	387.2	35,330	29.8	42.9	1,510,000	426,500	.46	3,541,000	69.9
103	Nov. 20	52.5	39.3	483.6	36,000	34.9	47.3	1,697,000	528,400	.41	3,212,000	79.1
104	Nov. 22	47.9	18.1	238.4	29,570	28.1	33.1	975,500	262,500	.48	3,716,000	58.7
105	Nov. 22	73.3	29.4	399.3	47,950	31.0	30.8	1,474,000	439,500	.43	3,353,000	95.1
106	Nov. 23	74.8	30.1	420.1	49,180	29.2	32.3	1,591,000	463,900	.44	3,430,000	97.6
107	Nov. 24	75.4	39.5	524.5	48,770	32.8	31.3	1,519,000	576,700	.34	2,634,000	96.5
108	Nov. 24	59.7	36.8	465.3	38,860	37.2	43.7	1,694,000	506,900	.43	3,342,000	76.8
109	Nov. 27	39.1	28.0	298.2	22,940	26.7	53.7	1,226,000	329,100	.48	3,728,000	44.9
110	Nov. 27	43.2	28.8	325.4	26,450	26.5	53.9	1,421,000	358,500	.51	3,965,000	52.3
111	Nov. 29	40.8	40.6	390.7	21,080	30.0	74.8	1,574,000	428,600	.47	3,672,000	41.4
112	Nov. 29	39.3	36.4	395.6	19,610	30.4	68.6	1,342,000	433,400	.40	3,095,000	38.4

TESTS ON DUPLEX PUMP AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Date.	Single strokes per minute.	Length of stroke. West.	Length of stroke. East.	Steam pressure by gauge.	Weight of condensed steam per hour. (Pounds.)	Total head. (Feet.)	M. E. P. Steam Cylinders. West. (Head end.)	M. E. P. Steam Cylinders. West. (Pump end.)	M. E. P. Steam Cylinders. East. (Head end.)	M. E. P. Steam Cylinders. East. (Pump end.)	M. E. P. Water Cylinders. West.	M. E. P. Water Cylinders. East.	Horse power. Steam cylinders.	Horse power. Water cylinders.	Horse power. (Output.)	Efficiency. (Per cent.)	Apparent capacity of pump. (Gallons.)	Capacity of pump by hose nozzles. (Gallons.)	Steam per horse power per hour.	B.T.U. per horse power per minute.	Duty. (Foot pounds per 1,000,000 B.T.U.)
1894.																					
March 19	101	8.59	8.73	49.2	640	46.5	10.57	10.15	9.23	9.97	22.01	21.62	4.40	4.10	3.85	87	322	328	145	2,004	12,010,000
March 30	99	11.40	10.10	58.5	840	62.7	12.80	12.61	12.51	12.88	....	....	6.78	....	5.92	87	390	374	125	2,070	13,920,000
March 15	126	8.70	8.90	53.2	906	70.9	15.02	14.83	15.05	14.45	32.71	33.01	8.33	7.86	7.30	88	410	410	109	1,800	16,150,000
March 20	129	8.79	9.03	51.4	1,100	75.4	15.17	14.37	16.31	15.28	33.47	35.23	8.88	8.50	7.90	89	424	415	124	2,048	14,330,000
April 2	127	9.67	9.40	55.6	1,246	79.1	14.00	15.89	16.71	14.77	....	....	9.36	....	8.56	91	446	429	133	2,205	13,680,000
March 15	131	9.21	9.32	49.1	1,235	82.6	15.89	14.89	17.83	14.88	36.19	37.61	9.74	9.63	9.09	93	448	436	127	2,047	14,700,000
April 3	114	11.70	11.07	55.6	1,261	93.7	18.71	19.66	19.04	18.71	....	....	12.48	....	11.10	89	479	469	101	1,674	17,540,000
March 27	119	11.49	11.07	51.4	1,332	96.7	17.25	17.25	19.75	17.98	....	....	12.18	....	11.34	93	493	464	109	1,809	16,980,000
March 20	147	9.11	9.23	48.9	1,560	98.6	19.61	21.57	22.01	18.70	44.36	45.90	13.86	13.02	11.90	86	494	478	113	1,860	15,240,000
March 22	141	9.59	9.85	48.4	1,728	102.9	19.66	21.89	21.33	18.96	46.14	45.46	14.11	13.46	12.62	89	504	486	122	2,023	14,590,000
April 3	153	9.50	9.50	54.0	1,469	106.6	19.49	18.95	22.17	19.51	....	....	14.69	....	13.70	93	536	509	100	1,655	18,690,000
March 23	145	9.57	9.93	48.0	1,626	107.7	22.06	21.59	23.66	20.10	....	....	15.56	....	13.48	87	520	496	104	1,726	16,570,000
March 16	150	9.34	9.74	49.2	1,710	111.5	21.57	21.36	24.39	21.51	50.92	51.32	16.06	15.74	14.50	90	528	514	106	1,760	16,890,000
March 16	153	9.40	9.67	48.4	1,910	117.0	22.37	24.03	26.92	21.64	52.33	55.24	17.46	16.86	15.50	89	537	525	109	1,805	16,230,000
April 2	163	9.33	9.50	52.9	1,768	123.7	23 45	24.99	25.25	23.59	....	....	18.85	....	17.12	91	566	548	94	1,552	19,310,000
March 29	135	11.60	11.10	53.8	1,668	123.9	20.91	26.11	24.69	22.28	....	....	18.24	....	16.82	92	568	538	92	1,530	19,850,000
March 22	156	10.90	10.26	47.2	2,056	131.9	25 13	26.31	29.64	23.77	58.24	58.07	21.00	19.80	18.80	90	584	565	98	1,619	18,280,000
March 19	134	9.79	10.21	48.1	2,045	134 4	26.93	25.56	28.19	24.63	58.16	62.88	20.67	20.24	19.00	92	573	561	99	1,636	18,590,000
March 23	193	10.09	10.31	45.6	2,577	180.2	31.91	30.24	38 57	31.92	....	....	32.95	....	30.59	93	726	672	78	1,291	23,730,000
March 26	195	9.90	10.30	43.8	2,704	183.5	33.80	32.09	39.99	32.50	....	....	34.31	....	31.38	91	724	677	79	1,300	23,220,000
March 27	175	11.77	11.79	45.6	2,594	203.4	34.36	38.29	41.71	38.33	....	....	39.55	....	36.30	92	757	707	66	1,083	27,980,000
March 29	180	11.74	11.66	46.5	2,778	203.9	36.35	38.27	41.57	39.51	....	....	41.20	....	37.57	91	774	730	67	1,110	27,030,000

FLOW OF STEAM TESTS.

Number of test.	Date.	Boiler pressure. (Gauge.)	Back pressure. (Gauge.)	Orifice pressure. (Gauge.)	Weight of condensed steam.	Calorimeter Tests.			Barometric pressure.	Weight of steam per hour by experiment.	Weight by thermo-dynamic equation.	Weight by Napier's formula.	Coefficient of flow from thermo-dynamic equation.	Coefficient of flow from Napier's formula.	Ratio of abs. back pressure to abs. boiler pressure.	Ratio of abs. orifice pressure to abs. boiler pressure.
						Boiler pressure. (Gauge.)	Pressure in calorimeter. (Gauge.)	Temperature in calorimeter.								
	1893.															
1	Oct. 2	109.1	8.9	62.8	154	108.0	2.7	143.1	14.7	308	311	312	.992	.986	.19	.63
2	Oct. 3	108.7	13.6	62.8	155	109.9	3.7	144.7	14.8	310	310	312	1.00	.995	.23	.63
3	Oct. 4	108.2	18.7	62.3	153	109.2	2.6	143.8	14.7	307	308	310	.997	.990	.27	.63
4	Oct. 4	107.7	23.7	62.2	151	108.8	3.5	143.7	14.7	303	307	309	.987	.980	.31	.63
5	Oct. 5	108.5	28.6	62.7	154	110.6	3.6	144.0	14.7	307	309	311	.994	.987	.35	.63
6	Oct. 6	108.8	33.7	62.9	153	110.4	3.6	144.4	14.8	305	310	312	.986	.979	.39	.63
7	Oct. 9	109.8	38.1	63.5	155	110.5	4.2	144.6	14.6	310	312	314	.995	.987	.42	.63
8	Oct. 10	109.8	43.3	63.1	156	112.7	2.8	144.9	14.7	311	311	314	1.00	.990	.47	.63
9	Oct. 11	108.4	47.7	62.8	154	110.6	3.7	144.9	14.8	307	309	311	.995	.988	.51	.63
10	Oct. 11	108.8	47.4	62.9	153	109.0	3.8	144.8	14.8	306	310	312	.988	.982	.50	.63
11	Oct. 12	111.1	53.5	63.0	149	111.4	4.3	145.0	14.8	309	316	318	.979	.972	.54	.62
12	Oct. 13	109.0	57.5	65.1	154	109.1	3.9	144.3	14.8	308	309	312	.998	.985	.58	.65
13	Oct. 13	109.0	62.1	67.5	150	109.2	3.8	144.4	14.8	300	306	310	.980	.970	.62	.66
14	Oct. 16	111.0	66.8	71.7	154	110.5	4.1	144.6	14.8	308	301	309	1.01	.997	.65	.69
15	Oct. 16	110.0	73.2	75.4	146	112.1	4.2	144.8	14.8	291	297	293	.982	.992	.71	.72
16	Oct. 17	109.8	81.5	82.6	133	109.9	4.1	145.1	14.9	266	276	269	.964	.988	.77	.78
17	Oct. 18	109.4	82.0	82.9	132	110.2	4.2	144.6	14.9	265	274	265	.967	1.00	.78	.79
18	Oct. 18	111.3	86.3	86.9	129	112.4	4.1	144.5	14.9	257	270	259	.953	.992	.80	.81
19	Oct. 20	108.9	3.6	62.8	157	108.8	3.6	142.2	14.9	313	311	313	1.01	1.00	.15	.63
20	Oct. 20	110.9	91.2	91.9	116	110.2	4.2	143.2	14.9	233	246	236	.946	.987	.84	.85
21	Oct. 23	109.3	96.7	96.8	99	111.3	4.1	142.1	14.9	199	204	193	.978	1.03	.90	.90
22	Oct. 23	109.3	101.0	100.9	83	109.4	3.7	142.2	14.9	165	171	160	.966	1.03	.93	.93
23	Oct. 24	110.9	105.3	105.3	70	111.5	4.1	140.2	14.7	141	146	134	.964	1.05	.96	.96
24	Oct. 25	109.4	4.3	63.4	154	109.0	5.1	143.6	14.6	308	311	313	.990	.983	.15	.63
25	Oct. 25	109.5	8.9	63.4	155	112.7	4.4	144.3	14.7	310	311	314	.997	.990	.19	.63
26	Oct. 26	109.6	13.6	63.3	155	108.0	4.2	143.7	14.8	311	310	313	1.00	.992	.23	.63
27	Oct. 27	110.2	18.8	63.9	153	112.1	4.8	144.2	14.8	306	313	316	.977	.970	.27	.63
28	Oct. 27	109.6	23.9	63.1	155	110.2	4.3	143.8	14.9	309	312	314	.991	.983	.31	.63
29	Oct. 30	111.5	28.6	64.4	157	111.0	4.3	144.7	14.9	313	316	319	.992	.982	.34	.63
30	Oct. 31	109.5	33.4	63.2	155	109.8	4.3	144.1	14.9	310	312	314	.994	.986	.39	.63
31	Nov. 1	110.3	38.4	63.9	155	105.7	4.1	142.9	14.9	309	314	316	.986	.978	.43	.63
32	Nov. 2	110.0	42.8	64.4	162	112.2	42.5	143.9	14.7	324	321	320	1.01	1.01	.45	.62
33	Nov. 3	110.1	47.7	63.9	154	110.6	4.4	143.9	14.7	309	313	315	.988	.980	.50	.63
34	Nov. 6	109.9	52.2	64.0	155	111.2	18.7	146.7	14.8	309	313	315	.987	.983	.54	.63
35	Nov. 6	110.1	57.1	65.2	153	110.1	4.6	143.5	14.8	306	316	315	.968	.970	.58	.64
36	Nov. 7	111.2	61.9	62.8	154	110.4	4.4	144.2	15.0	308	317	317	.973	.973	.61	.62
37	Nov. 8	109.5	66.1	70.3	154	109.7	5.3	142.0	14.9	308	304	306	1.01	1.01	.65	.68
38	Nov. 8	110.5	71.7	74.8	147	110.1	4.6	144.5	14.9	296	300	299	.981	.986	.69	.72
39	Nov. 9	110.5	76.8	78.9	143	117.9	5.2	144.8	14.7	286	291	286	.982	.988	.73	.75
40	Nov. 13	109.6	81.7	82.5	135	110.5	3.8	143.9	14.8	270	276	267	.979	1.01	.78	.78
41	Nov. 13	112.3	86.5	87.3	128	110.3	4.8	142.8	14.8	257	272	263	.942	.974	.80	.80
42	Nov. 15	110.3	91.5	91.2	116	109.4	4.9	142.9	14.6	233	245	230	.950	1.01	.85	.85
43	Nov. 15	110.8	96.9	96.9	102	110.4	5.0	142.4	14.5	204	220	202	.925	1.01	.89	.89
44	Nov. 17	111.1	101.2	101.2	90	111.1	4.9	142.9	14.8	180	185	175	.975	1.03	.92	.92
45	Nov. 17	111.9	106.1	105.9	72	110.3	5.0	136.2	14.7	143	149	136	.960	1.05	.95	.95
46	Nov. 20	109.8	4.6	63.0	155	109.8	4.6	142.3	14.7	309	313	314	.988	.983	.15	.62
47	Nov. 20	109.2	4.4	62.8	154	109.3	4.4	142.3	14.7	307	311	313	.990	.983	.15	.63
48	Nov. 22	109.7	4.6	63.1	154	109.5	4.6	142.0	14.6	309	312	314	.988	.983	.15	.63
49	Nov. 22	110.0	4.8	63.3	150	110.2	4.8	142.7	14.6	301	313	315	.961	.956	.16	.63
50	Nov. 23	109.7	4.5	63.0	155	109.7	4.5	141.3	14.6	310	313	314	.993	.989	.15	.62
51	Nov. 27	109.4	4.3	63.0	155	109.4	4.3	143.8	15.0	309	312	314	.992	.985	.15	.63
52	Nov. 29	111.6	5.0	68.7	160	114.2	5.0	144.4	14.7	319	313	319	1.02	1.00	.16	.66

TESTS ON HORIZONTAL BELT MACHINE, 1890.

Number of test.	Horse power.	East Belt.		West Belt.		$T_1 + T_2$.	T_1.		T_1/T_2.		f	
		Speed.	Slip.	Speed.	Slip.		East belt.	West belt.	East belt.	West belt.	East belt.	West belt.
1	2	3	4	5	6	7	8	9	10	11	12	13
1	6.15	2123.5	5.2	2120.5	2.4	700	398	398	1.318	1.318	.09	.09
2	6.79	2212.7	3.3	2210.0	3.6	700	401	401	1.341	1.341	.09	.09
3	8.00	2178.1	4.0	2175.3	3.2	600	361	361	1.510	1.510	.13	.13
4	9.10	2046.3	3.1	2043.7	3.6	650	399	399	1.590	1.590	.15	.15
5	9.81	2205.5	4.8	2201.9	4.0	600	374	374	1.655	1.655	.16	.16
6	11.23	2152.1	3.6	2148.5	5.2	700	436	436	1.652	1.652	.16	.16
7	12.96	2169.6	7.6	2164.2	4.8	700	448	449	1.778	1.789	.18	.19
8	14.50	2149.7	6.8	2144.5	5.2	650	437	437	2.052	2.052	.23	.23
9	15.72	2092.5	6.8	2087.0	5.9	650	449	450	2.234	2.250	.26	.26
10	16.01	2153.9	8.0	2145.7	10.0	600	422	423	2.371	2.390	.27	.28
11	16.43	2186.4	6.4	2181.1	6.1	700	474	475	2.097	2.111	.24	.24
12	16.97	2113.0	29.4	2093.0	12.3	600	433	434	2.593	2.614	.30	.31
13	17.56	2147.4	14.7	2132.7	16.3	600	435	436	2.636	2.659	.31	.31
14	17.98	2182.3	7.6	2175.5	7.6	700	486	487	2.271	2.286	.26	.26
15	18.01	2182.7	7.6	2176.1	7.2	700	486	487	2.271	2.286	.26	.26

NOTE. — Belts used were 7″ leather-laced double belts.

TESTS ON HORIZONTAL BELT MACHINE, 1891.

Number of test.	Horse power.	East Belt.		West Belt.		$T_1 + T_2$.	T_1.		T_1/T_2.		f		$T_1 + T_2$ per horse power.
		Speed.	Slip.	Speed.	Slip.		East belt.	West belt.	East belt.	West belt.	East belt.	West belt.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	2.6	1536	1.8	1537	2.3	358	206.9	206.9	1.37	1.37	.10	.10	137.7
2	2.6	1532	2.2	1533	2.6	334	195.0	195.0	1.40	1.40	.11	.11	128.5
3	2.7	1547	2.6	1549	2.8	303	180.3	180.3	1.47	1.47	.12	.12	112.2
4	2.7	1556	2.9	1558	2.4	295	176.1	176.1	1.48	1.48	.13	.13	109.3
5	3.6	1536	3.0	1538	3.6	348	212.2	213.1	1.57	1.57	.14	.14	96.7
6	3.6	1541	3.4	1544	5.5	261	169.5	168.4	1.83	1.84	.19	.19	72.5
7	3.7	1551	3.3	1554	4.0	298	188.3	188.3	1.72	1.72	.17	.17	80.6
8	4.5	1511	3.4	1513	5.5	358	228.1	228.0	1.76	1.75	.18	.18	79.6
9	4.6	1524	4.2	1528	5.1	331	215.3	215.1	1.86	1.86	.20	.20	72.0
10	5.5	1522	5.7	1527	6.7	265	193.0	190.8	2.61	2.64	.31	.31	48.2
11	5.6	1535	4.6	1539	4.3	429	274.6	274.5	1.78	1.78	.18	.18	76.6
12	5.6	1541	4.2	1545	4.7	397	256.9	259.7	1.87	1.85	.20	.20	70.9
13	5.5	1525	4.9	1529	5.9	350	233.9	234.7	2.03	2.02	.23	.22	63.6
14	5.6	1533	5.3	1537	5.5	342	231.2	231.4	2.09	2.08	.24	.23	61.1
15	6.5	1524	4.5	1528	6.3	390	265.3	265.1	2.13	2.12	.24	.24	60.0
16	6.6	1537	6.1	1542	6.3	374	256.9	258.7	2.23	2.21	.25	.25	56.7
17	7.4	1507	6.9	1513	5.9	412	285.9	287.6	2.30	2.28	.27	.26	55.7
18	7.4	1505	6.6	1511	6.2	390	276.0	275.7	2.42	2.41	.28	.28	52.7
19	7.5	1525	6.2	1530	6.7	403	281.0	283.7	2.36	2.32	.27	.27	53.7
20	7.5	1524	6.1	1529	7.5	377	269.6	269.3	2.51	2.50	.29	.29	50.3
21	7.5	1520	7.3	1527	7.5	351	256.7	256.4	2.73	2.72	.32	.32	46.8
22	8.3	1490	6.7	1496	8.1	390	286.7	286.3	2.78	2.76	.33	.32	47.0
23	9.3	1507	8.9	1515	8.2	391	297.1	296.5	3.16	3.14	.37	.37	42.0
24	8.3	1499	8.9	1507	9.8	339	260.1	260.6	3.34	3.28	.38	.38	40.9
25	8.3	1503	8.5	1511	10.1	320	250.9	250.2	3.63	3.59	.41	.41	38.6
26	9.2	1497	9.8	1506	10.1	346	274.1	273.5	3.81	3.77	.43	.42	37.6
27	9.2	1490	10.2	1500	9.8	324	263.5	262.9	4.35	4.30	.47	.46	35.2
28	10.1	1482	11.7	1493	11.7	347	284.5	285.7	4.70	4.51	.49	.48	34.4
29	10.0	1473	11.0	1483	11.7	334	278.6	277.8	5.03	4.94	.51	.51	33.4
30	9.3	1498	10.5	1508	11.3	297	250.3	250.6	5.48	5.29	.54	.53	31.9

NOTE 1. — Belts were 4″ laced-leather single belts.

" 2. — Speed of belt is average of surface speed of pulleys.

Number of test.	Horse power.	East Belt.			West Belt.			$T_1 + T_2$.		T_1.		Distance between shafts. East belt.	Turns of east belt.	T_1/T_2.		f	
		Speed driving pulley.	Speed driven pulley.	Slip.	Speed driving pulley.	Speed driven pulley.	Slip.	East belt.	West belt.	East belt.	West belt.			East belt.	West belt.	East belt.	West belt.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3	5.30	1625.7	1623.2	2.5	1623.1	1619.8	3.3	600	600	354	354	....	.....	1.439	1.439	.12	.12
2	5.56	1706.0	1703.2	2.8	1703.2	1700.3	2.9	600	600	354	354	....	.....	1.439	1.439	.12	.12
16	5.80	1783.7	1781.7	2.0	1781.7	1779.3	2.4	756	909	432	508	18.493	40.00	1.333	1.267	.09	.08
50	7.08	1768.4	1768.0	0.4	1768.0	1749.5	18.5	1,300	500	716	317	....	.....	1.226	1.732	.07	.17
21	8.65	1797.1	1793.5	3.6	1793.5	1789.9	3.6	703	837	431	498	18.493	40.39	1.584	1.469	.15	.12
17	8.68	1802.9	1799.8	3.1	1799.8	1796.2	3.6	729	896	444	528	18.493	40.46	1.558	1.435	.14	.11
35	8.85	2243.4	2087.4	156.0	2087.4	1848.0	239.4	300	300	218	224	18.363	48.81	2.059	2.948	.31	.34
26	8.99	1604.8	1600.7	4.1	1600.7	1596.6	4.1	632	778	409	482	18.493	35 91	1.834	1.629	.19	.16
32	9.59	1720.2	1712.6	7.6	1712.6	1705.5	7.1	530	610	357	398	18.483	38.58	2.063	1.968	.23	.22
29	9.80	1755.5	1750 3	5.2	1750.3	1744.0	6.3	560	560	372	373	18.483	39.39	1.979	1.995	.22	.22
22	10.04	1795.5	1790.7	4.8	1790.7	1786.8	3.9	683	817	434	501	....	.....	1.742	1.585	.18	.15
6	10.40	1632.1	1627.3	4.8	1627 2	1621.9	5.3	723	817	467	514	18.436	36.43	1.829	1.697	.19	.17
25	10.45	1871.7	1867.0	4.7	1867.0	1862.3	4.7	676	798	421	491	18.493	41.97	1.652	1.602	.16	.15
23	10.58	1656.3	1651.8	4.5	1651.8	1647.4	4.4	683	817	447	514	18.493	37.09	1.895	1.694	.20	.17
13	10.69	1682.2	1674.6	7.6	1674.6	1666.6	8.0	450	450	330	331	18.413	38.21	2.750	2.782	.32	.33
11	10.75	1688.0	1682.4	5.6	1682.4	1677.2	5.2	667	733	439	472	....	.....	1.926	1.809	.21	.19
12	10.99	1729.2	1722.9	6.3	1722.9	1714.9	8.0	450	450	330	331	....	.....	2.750	2.782	.32	.33
37	11.12	1751.2	1742.9	8.3	1742.9	1736.2	6.7	600	600	405	405	....	.....	2.039	2.039	.23	.23
14	11.27	1777.1	1768.0	9.1	1768.0	1760.1	7.9	417	483	313	347	....	.....	3.010	2.526	.35	.29
18	11.43	1794.3	1790.7	3.6	1790.7	1784.4	6.3	729	896	470	553	18.493	40.60	1.816	1.613	.19	.15
7	11.77	1649.9	1641.2	5.7	1641.2	1635.6	5.6	717	783	476	510	18.436	36.51	1.980	1.869	.22	.20
19	11.85	1863.0	1857.9	5.1	1857.9	1851.6	6.3	717	863	464	537	18.493	41.75	1.832	1.649	.19	.16
15	12.37	1730.4	1724.8	5.6	1724.8	1719.6	5 2	816	969	526	603	18.493	38.85	1.813	1.649	.19	.30
27	16.02	2253.2	2245 2	8.0	2245.2	2235.2	10.0	530	530	383	383	18.483	50.37	2.606	2.606	.30	.30
36	17 18	2179.8	2170.2	9.6	2170.2	2159.9	10.3	600	600	430	431	....	.....	2.530	2.541	.30	.30
33	17.35	2209.3	2195 4	13.9	2195.4	2182.3	13.1	530	610	395	436	....	.....	2.028	2.508	.34	.29
30	17.35	2203.0	2194.2	8.8	2194.2	2183.4	10.8	560	560	410	411	....	.....	2.734	2.748	.32	.32
39	17.40	2205.3	2197.3	8.0	2197.3	2188.9	8.4	683	817	472	539	....	.....	2.236	1.938	.26	.21
31	17.46	2223.8	2207.8	16.3	2207.5	2196.8	10.7	560	560	410	411	....	.....	2.734	2.748	.32	.32
43	17.55	2222.6	2216.6	6.0	2216.6	2208.2	8.4	858	792	560	527	....	.....	1.880	1.992	.20	.22
28	17.74	2249.3	2242.5	6.8	2242.5	2232.1	10.4	560	560	410	411	18.483	50.53	2.734	2.748	.32	.32
41	19.19	2215.9	2206.7	9.2	2206.7	2196.7	10.0	675	795	481	541	....	.....	2.480	2.132	.29	.24
24	20.69	2194.4	2184.0	10.4	2184.0	2174.0	10.0	683	817	498	565	....	.....	2.694	2.243	.32	.26

NOTE 1. — Belts used were laced rubber belts, 6″ wide and ¼″ thick.
" 2. — West belt in test No. 50 was a laced leather belt. East belt was ¼″ thick.
NOTE 3. — Circumferences of pulleys on which east belt ran were 7.844′ and 7.849′.
" 4. — Arc of contact was 180°.

TESTS ON HORIZONTAL BELT MACHINE, 1893.

Date.	Horse power.	Speed of east belt. (Feet per minute.)	Speed of west belt. (Feet per minute.)	Slip of east belt. (Feet per minute.)	Slip of west belt. (Feet per minute.)	$T_1 + T_2$.	T_1, east belt.	T_1, west belt.	T_2, east belt.	T_2, west belt.	$\frac{T_1}{T_2} = e^{f\theta}$ f east belt.	f west belt.
Oct. 19	3.75	2,253	2,254	+ .1	4.6	600	327	327	273	273	.057	.057
Sept. 28	5.50	2,249	2,249	2.5	4.6	530	306	306	224	224	.099	.099
Sept. 29	5.51	2,249	2,248	.9	6.9	500	290	290	210	210	.103	.103
Nov. 6	5.54	2,264	2,262	3.3	5.4	700	390	390	310	310	.073	.073
Oct. 18	5.59	2,284	2,282	.9	7.8	500	290	290	210	210	.103	.103
Nov. 2	7.10	2,199	2,198	2.5	4.5	700	403	403	297	297	.097	.097
Nov. 8	7.21	2,232	2,231	3.3	4.5	400	254	254	146	146	.176	.176
Oct. 2	7.27	2,250	2,249	3.2	5.4	500	303	303	197	197	.137	.137
Oct. 18	7.29	2,256	2,255	2.5	6.2	600	354	354	246	246	.116	.116
Nov. 13	8.76	2,182	2,179	2.5	9.1	400	266	266	134	134	.218	.218
Oct. 23	8.79	2,189	2,187	2.5	6.8	600	367	367	233	233	.145	.145
Oct. 31	8.80	2,201	2,202	1.8	6.8	700	416	416	284	284	.121	.121
Oct. 3	8.94	2,228	2,225	4.1	7.7	500	317	317	183	183	.175	.175
Oct. 4	8.94	2,226	2,224	4.1	6.1	500	317	317	183	183	.175	.175
Nov. 13	8.99	2,242	2,238	4.9	8.5	400	266	266	134	134	.218	.218
Nov. 1	9.00	2,234	2,233	1.8	6.9	700	416	416	284	284	.121	.121
Nov. 22	10.44	2,177	2,172	5.7	9.1	400	279	279	121	121	.266	.266
Nov. 8	10.52	2,195	2,191	5.6	8.3	400	279	279	121	121	.266	.266
Nov. 22	10.55	2,201	2,197	6.4	8.4	400	279	279	121	121	.266	.266
Oct. 4	10.59	2,207	2,204	5.6	7.6	500	329	329	171	171	.208	.208
Nov. 1	10.60	2,209	2,205	3.3	9.2	700	429	429	271	271	.146	.146
Oct. 16	10.63	2,215	2,212	5.7	6.8	600	379	379	221	221	.172	.172
Oct. 11	10.65	2,219	2,218	4.1	5.3	600	379	379	221	221	.172	.172
Oct. 9	10.65	2,221	2,215	4.9	13.9	500	329	329	171	171	.208	.208
Nov. 3	12.02	2,158	2,155	7.2	3.6	700	442	442	258	258	.171	.171
Oct. 9	12.13	2,203	2,198	6.5	9.2	500	341	341	159	159	.243	.243
Nov. 10	12.14	2,179	2,173	10.4	7.5	400	292	292	108	108	.317	.317
Nov. 21	12.18	2,185	2,179	7.2	9.1	400	292	292	108	108	.317	.317
Nov. 23	12.22	2,192	2,186	8.9	9.2	400	292	292	108	108	.317	.317
Nov. 24	12.27	2,202	2,196	8.0	10.0	400	292	292	108	108	.317	.317
Oct. 5	12.27	2,202	2,198	6.4	8.4	500	342	342	158	158	.246	.246
Nov. 28	13.56	2,137	2,129	8.9	11.4	400	305	305	95	95	.372	.372
Nov. 27	13.74	2,166	2,159	7.3	13.0	400	305	305	95	95	.372	.372
Nov. 7	13.76	2,168	2,163	19.0	—4.2	700	455	455	245	245	.197	.197
Nov. 9	13.77	2,172	2,146	15.9	42.1	400	304	306	96	94	.367	.376
Nov. 15	13.78	2,170	2,162	11.2	10.7	400	305	305	95	95	.372	.372
Nov. 16	13.79	2,171	2,166	3.9	11.4	400	305	305	95	95	.372	.372
Nov. 14	13.80	2,177	2,168	12.7	10.8	400	305	305	95	95	.372	.372
Nov. 17	13.80	2,175	2,168	10.4	10.7	400	305	305	95	95	.372	.372
Nov. 20	13.84	2,182	2,173	12.7	10.7	400	305	305	95	95	.372	.372
Nov. 6	13.85	2,179	2,176	4.2	8.4	700	455	455	245	245	.197	.197
Nov. 27	13.88	2,187	2,180	8.9	10.7	400	305	305	95	95	.372	.372
Nov. 29	13.90	2,190	2,184	8.0	10.7	400	305	305	95	95	.372	.372
Oct. 6	13.94	2,196	2,189	7.2	10.8	500	355	355	145	145	.285	.285
Oct. 12	13.98	2,204	2,198	6.4	10.7	600	405	405	195	195	.233	.233
Nov. 17	13.99	2,205	2,198	8.1	10.8	400	305	305	95	95	.372	.372
Nov. 20	14.07	2,219	2,212	10.4	10.0	400	305	305	95	95	.372	.372
Oct. 13	14.14	2,227	2,222	6.4	10.0	600	405	405	195	195	.233	.233
Nov. 29	15.41	2,164	2,155	12.0	11.5	400	318	318	82	82	.431	.431
Nov. 15	15.45	2,172	2,162	15.1	11.5	400	318	318	82	82	.431	.431
Oct. 6	15.54	2,181	2,174	8.9	13.1	500	368	368	132	132	.326	.326
Oct. 16	15.62	2,190	2,185	6.5	8.3	600	418	418	182	182	.264	.264
Nov. 10	15.63	2,201	2,189	19.0	11.5	400	317	318	83	82	.427	.431
Oct. 25	17.05	2,165	2,159	5.7	11.4	600	430	430	170	170	.295	.295
Oct. 11	17.06	2,187	2,163	30.9	23.3	500	379	380	121	120	.363	.367
Oct. 30	18.90	2,184	2,163	15.1	31.9	600	443	444	157	156	.330	.333

NOTE. — 6″ laced rubber belts.

TESTS ON WHEELER CONDENSER, 1892.

Date.	Pressure of entering steam. °C.	Temperature of entering steam. °C.	Temperature of condensed steam. °C.	Temperature of cold condensing water. °C.	Temperature of hot condensing water. °C.	Weight of steam condensed per hour.	Weight of condensing water per hour.	Steam condensed per pound of water.	Steam condensed per square foot of steam surface per hour.	Steam condensed per square foot of water surface per hour.
1892.										
Dec. 2	2.3	104.2	52.8	5.6	43.5	683.2	10,429	.066	7.24	7.98
Dec. 2	1.2	103.7	45.2	5.2	31.7	642.0	14,419	.044	6.80	7.50
Dec. 5	3.0	121.3	53.5	5.2	38.2	1083.0	18,738	.058	11.47	12.65
Dec. 5	4.0	125.4	62.9	4.5	43.2	1280.5	18,302	.067	13.56	14.96
Dec. 7	3.3	121.4	58.9	3.6	39.5	1148	18,382	.062	12.16	13.41
Dec. 9	1.4	117.3	44 3	4.1	33.2	762	15,524	.049	8.07	8.90
Dec. 12	1.1	112.3	39.2	3.7	26.9	692	17,548	.039	7.33	8.08
Dec. 14	0.6	108.7	37.1	4.4	27.7	509.5	12,992	.039	5.40	5.95
Dec. 16	1.4	120.8	54.8	3.5	40.4	795.5	12,708	.063	8.43	9.29
Dec. 23	0.0	101.5	17.2	2.5	19.4	142 3	5,111	.028	1.50	1.60

TESTS ON A MACK INJECTOR, 1893.

Date.	Steam pressure at injector. (Gauge.)	Temperature of steam at injector. °C.	Temperature of suction. °C.	Temperature of discharge. °C.	Suction gauge. (Inches of mercury.)	Delivery gauge pressure.	Water fed per hour	Water delivered per hour.	Steam used per hour.	Water fed per pound of steam.	Water fed per pound of steam by temperatures.
1893.											
Feb. 2	39.1	141.4	7.48	71.48	9.0	7.5	7934.1	884.0	905.9	8.8	9.0
Feb. 3	37.6	140.3	10.10	72.80	8.6	21.6	7817.0	8699.2	882 2	8.9	9.2
Feb. 6	32.5	137.3	12.50	63.57	10.3	16.3	8256.8	9057.0	800.2	10.3	11.4
Feb. 7	39.9	142.1	12.60	80.75	8.7	25.8	7357.5	8270.2	912.7	8.1	8.2
Feb. 10	38.6	141.0	3.80	69.80	8.8	67.1	7597.6	8498.0	900.4	8.4	8.6
Feb. 13	38.3	141.1	10.90	77.18	10.0	93.8	7192.1	8091.0	898.9	8.0	8.5
Feb. 14	38.7	141.1	10.83	73.46	8.0	49.8	8006.0	8910.0	904.0	8.9	9.2
Feb. 16	39.8	141.7	14.97	85 35	9.6	66.5	7013.4	7927 5	914.1	7.7	8.0
Feb. 17	27.6	132.2	8.94	56.17	9.8	64.9	8646.0	9357.0	711.7	12.1	12.5
Feb. 20	12.8	118.1	12.15	53.91	9.3	10.2	6667.0	7131.0	464.3	14.4	14.1
Feb. 21	38.3	140.8	10.90	76.90	9.0	45.1	7436.2	8325.0	888.8	8.4	8.6
Feb. 23	36.9	141.6	11.44	76.42	9.0	57.3	7779.2	8697.8	918.6	8.5	8.8
Feb. 24	36.8	120.2	11.60	73.60	9.0	59.3	7789 4	8653.8	864.1	9.0	9.3
Feb. 27	39.1	141.2	12.93	76.34	9 1	78.4	7907.0	8813 0	905.6	8.7	9.0
Feb. 28	39.1	141.3	12.11	75.52	10.0	63.8	7861.4	8766.0	904.6	8.7	9.0

TESTS ON INJECTOR AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Number of test.	Date.	Boiler pressure by gauge.	Suction in inches of mercury.	Delivery pressure. (Gauge.)	Suction temperature. °C.	Intermediate temperature. °C.	Delivery temperature. °C.	Water fed per hour.	Water delivered per hour.	Steam used per hour.	Water fed per pound of steam.	Water fed per pound of steam by temperatures.	Lifter First.				Forcer First.			
													Water lifted per pound of steam in lifter.	Steam used per hour in lifter.	Steam used per hour in forcer.	Water forced per pound of steam in forcer.	Water forced per pound of steam in forcer.	Steam used per hour in forcer.	Steam used per hour in lifter.	Water lifted per pound of steam in lifter.
	1893.																			
1	Feb. 4	105.9	6.6	90.7	8.07	21.9	59.1	2,446	2,663	218	11.2	11.6	45.3	54.0	163.7	15.3	15.9	157.8	59.9	40.8
2	Feb. 5	106.3	10.5	132.5	8.9	23.8	65.9	2,500	2,753	252	9.9	10.2	42.9	58.3	194.3	13.2	13.8	185.7	66.8	37.4
3	Feb. 8	106.5	15.1	113.0	10.6	28.6	79.4	1,897	2,124	228	8.2	8.3	34.5	53 7	173.8	11.2	11.2	174.7	52.8	35.1
4	Feb. 9	107.1	11.1	114.1	7.2	22.7	65.9	2,321	2,556	235	9.9	9.9	40.3	57.6	117.4	13.4	13.5	176.4	58.6	39.6
5	Feb. 9	109.5	9.3	110.0	11.5	26.8	69.3	2,321	2,542	221	10.5	10.0	40.7	57.1	163.5	14.6	13.6	173.8	46.7	47.3
6	Feb. 12	106.3	5.5	110.2	6.8	21.3	63.9	2,372	2,596	224	10.6	10.2	43.3	54.8	169.3	14.3	13.7	176.3	47.8	49.6
7	March 3	105.8	4.8	55.3	7.5	21.0	47.5	2,542	2,715	172.9	14.7	15.1	46.6	54.5	118.4	21.2	22.7	114.5	58.4	43.6
8	March 4	108.0	4.9	112.0	11.2	26.0	67.7	2,250	2,464	214	10.5	10.3	42.1	53.4	160.3	14.4	13.9	165.6	48.1	46.0
9	March 10	102.5	11.5	72.5	19.7	35.9	81.1	2,028	2,243	215	9.2	9.2	37.9	53.5	161.5	12.9	12.2	169.8	45.2	44.9
10	March 11	108.2	11.0	53.4	13.6	30.4	75.6	2,105	2,332	227	9.3	9.2	37.1	56.8	171.0	12.3	12.6	171.2	15.9	38.0
11	March 14	109.2	5.8	37.0	7.3	22.7	64.1	2,419	2,649	229	10.5	10.3	40.1	60.4	169.5	14.6	14.2	174.9	55.0	44.0
12	March 15	106.6	10.0	83.6	8.0	23.3	66.5	2,250	2,467	217	10.4	9.9	40.4	55.8	161.4	14.3	13.5	170.7	46.4	48.5
13	March 17	110.5	11.5	36.1	14.5	30.0	77.2	2,087	2,319	234	9.0	9.1	39.9	52.4	179.3	11.9	12.1	177.3	54.4	38.4
14	March 17	106 9	11.8	37.1	8.0	23.9	68.6	2,286	2,476	249	9.0	9.6	39.3	56 7	192.0	11.9	13.0	177 5	71.2	31.3
15	March 18	107.6	3.5	107.3	7.0	22.0	64.0	2,358	2,596	238	9 9	10 3	41.4	57.0	181.0	13.3	14.0	173.5	64.6	36.5
16	March 21	107.9	4 5	130.6	18.0	33.6	76.5	2,250	2,485	235	9.6	9 8	39.6	56.8	178.3	12.8	13.3	174.0	61.0	36.9
17	March 22	108.8	6.3	74.3	8.8	23.4	67.0	2,324	2,556	232	10.0	10.0	42.9	54.2	177.8	13.4	13.3	177.9	54.0	43.0
18	March 22	108.8	3.0	59.9	8.3	23.4	65 0	2,335	2,561	227	10.3	10.3	41.4	56.5	170.0	14.1	14.0	170.5	56.0	41.7
19	March 25	111.3	3.4	51.8	11.5	27.0	70.3	2,323	2,557	235	9.9	9.8	40.2	57.7	176.9	13.5	13 3	178.4	56.2	41.4
20	March 28	112.4	15.0	25.3	11.3	33.0	91.2	1,553	1,770	217	7.1	7.0	28.5	54.5	162.1	9.9	9.5	168.1	48.6	32.0
21	March 28	111.2	9.4	82.8	19.5	35.4	79 7	2,109	2,337	228	9.3	9.4	38 8	54.4	173.4	12.5	12.7	170.0	57.5	36.7
22	March 29	110.8	8.4	117.1	9.7	24.8	67.7	2,246	2,465	221	10.2	10 0	41.3	54.4	165.7	13.9	13.5	169.8	50.3	44.7
23	March 29	110.5	8.6	60.0	14.3	29.6	73.1	2,195	2,415	220	10.0	9.8	40 6	54.8	164.7	13.6	13.2	170.0	49.0	44.6
24	March 31	110.1	11.6	80.4	10.7	27.0	74.6	2,000	2,234	234	8.6	9.0	38.2	52.3	181.7	11.3	12.0	171.5	62.6	32.0
25	April 1	111.3	10.9	80.7	15.2	30.4	78.3	2,065	2,300	236	8.8	9.0	40.8	50.6	184.9	11.4	11.9	178.9	56.6	40.6
26	April 1	109.8	13.4	90.0	10.0	25.2	68.7	2,240	2,462	222	10.1	10.2	41.0	54.6	167.2	13.7	13.9	172.1	49.7	45.0
27	April 4	108.1	7.0	59.8	19.2	34.7	78.1	2,175	2,395	220	9.9	9.7	39.8	54.6	165.3	13.5	13.1	170.2	49.7	43.8
28	April 4	108.5	11.5	69.5	12.9	28.9	76.2	2,003	2,234	232	8.7	9.0	39.0	51.4	180.2	11.4	12.1	171.1	60.5	33.1
29	April 5	109.6	9.0	49.9	15.0	30.5	73.2	2,270	2,494	224	10.1	9.9	40.0	56.7	167.4	13.9	13.4	172.8	51.3	44 2
30	April 8	111.1	9.3	66.9	18.5	34.7	79.4	2,048	2,302	254	8.1	9.3	38.1	53.8	200.2	10.5	12.7	168 3	85.7	23.9
31	April 11	98.4	11.0	70.7	15.1	30.0	71.7	2,120	2,334	214	9.9	10.2	46.5	50.7	163.5	13.3	13.7	158.4	53.8	38.0
32	April 11	104.1	12.2	45.2	13.2	29.7	77.6	1,918	2,148	230	8.3	8.8	37.6	51.0	179.2	11.0	11.9	167.1	63.1	30.4

TESTS ON INJECTOR AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY. — *Concluded.*

Number of test.	Date.	Boiler pressure by gauge.	Suction in inches of mercury.	Delivery pressure. (Gauge.)	Suction temperature. °C.	Intermediate temperature. °C.	Delivery temperature. °C.	Water fed per hour.	Water delivered per hour.	Steam used per hour.	Water fed per pound of steam.	Water fed per pound of steam by temperatures.	Lifter First.				Forcer First.			
													Water lifted per pound of steam in lifter.	Steam used per hour in lifter.	Steam used per hour in forcer.	Water forced per pound of steam in forcer.	Water forced per pound of steam in forcer.	Steam used per hour in forcer.	Steam used per hour in lifter.	Water lifted per pound of steam in lifter.
	1893.																			
33	April 12	111.1	11.1	60.8	12.4	28.4	75.7	2,043	2,271	228	9.0	9.1	39.8	51.4	176.7	11.9	12.1	173.5	54.5	37.5
34	April 12	111.0	11.0	89.5	14.2	31.1	78.9	1,973	2,191	218	9.1	8.8	36.6	53.9	164.0	12.4	11.9	170.1	47.8	41.2
	1894.																			
35	March 20	101.1	2.9	95.0	17.8	32.8	72.9	2,290	2,506	216	10.6	10.4	41.2	55.5	160.9	14.6	14.3	163.8	52.6	43.5
36	March 20	105.3	3 5	97.5	12.5	26.8	68.5	2,369	2,582	213	11.1	10.3	43.4	54.6	158.6	15.3	13.9	173.5	39.7	59.7
37	March 22	90.7	9.8	101.6	17.8	32.5	71.3	2,043	2,239	196	10.4	10.7	41.9	40.7	147.4	14.2	14.8	141.9	54.2	37.7
38	March 23	105.5	13.3	101.7	16.4	37.5	93.7	1,626	1,852	226	7.2	7.2	29.1	55.9	170.0	9.9	9.8	171.2	54 7	29.7
39	March 26	91.1	13 7	85.6	21.3	39.2	88.0	1,667	1,855	188.4	8.9	8.3	27.0	61.8	126.8	13.7	11.4	150.1	38.5	43.3
40	March 26	94.6	12.5	108.8	13.2	29 2	73.7	1,943	2,143	200	9.7	9.5	38.7	50.3	149.9	13.3	12.9	154 7	45 5	42.7
41	March 27	103.7	4.5	105.6	15.2	29.5	70.9	2,323	2,548	225	10.3	10.4	43.4	53.5	171.8	13.8	13.9	170.9	54.4	42 7
42	March 27	103.5	5 9	87.1	11.7	27.0	68.9	2,315	2,528	213	10 9	10.1	40.7	56.8	156.2	15.2	13.8	170.7	42.3	54.7
43	March 29	94.0	13.5	94.4	17.8	36.0	83.1	1,782	1,964	181.8	9.8	8.7	33.9	52.5	129.3	14.2	12.0	150.7	31.1	57.3
44	March 29	104.7	13.6	91 6	9.9	30.1	82.7	1,743	1,948	205	8.5	7.8	30.9	56.5	148.3	12.1	10.8	164 9	39.9	43.7
45	March 30	96 1	12.4	101.0	11.5	28.2	72.1	1,920	2,108	188	10.2	9.6	37.4	51.4	136.8	14.4	13.2	148 7	39.5	48.6
46	April 5	100.8	11.5	89.0	16.0	32.5	74.9	2,046	2,253	207	9.9	9.8	37.7	54.2	152.4	13.8	13.6	154.6	52.0	39.3
47	April 6	93.5	10.3	87.7	15.7	30.8	70.2	2,144	2,333	189	11.3	10.6	40.8	52.6	136.4	16.1	14.6	149.6	39.4	54.4
48	April 9	94.6	9.7	88.1	19.6	34.3	73.3	2,096	2,280	184	11.4	10.8	42.3	49.5	134.9	15.9	14.8	144.6	39.8	52.7
49	April 10	96.0	10.6	74 0	16.4	30.8	72.0	2,156	2,354	198	10.9	10.4	43.2	49.9	148.4	14.8	14.0	156.6	41.7	51.7
50	April 10	106.1	10.5	23.8	10.6	26.4	70.1	2,623	2,898	273	9.6	9.8	39.8	66.0	207.0	13.0	13.3	202.5	70.3	37.3

BOILER TESTS.

Test number.	Date.	Boiler number. (Old numbering.)	Duration of test. (Hours.)	Pressure of air.	Average Gauge pressure.	Grate area. (Square feet.)	Heating surface. (Square feet.)	Pounds of coal burned, including coal equivalent of wood.	Total refuse from coal.	Total water pumped into the boiler.	Air per pound of coal. (Pounds.)	Air per pound of combustible. (Pounds.)	Quality of steam.	Equivalent water evaporated into dry steam from and at 212° F. per pound of coal.	Equivalent water from and at 212° F. per pound of combustible.	Coal burned per sq. ft. of Grate per hour.	Water from and at 212° F. per sq. ft. heating surface per hour.	Remarks.
	1887.																	
1	Dec. 8	4	10	14.88	72.5	39.17	1,080	2,711	314	24,426	13.2	14.9	.991	9.5	10.7	9.29	2.38	
2	Dec. 9	4	10	15.0	71.3	39.17	1,086	2,820	367	25,534	14.5	16.6	.990	9.67	10.9	9.67	2.48	
3	Dec. 13	4	10	14.9	72.6	39.17	1,086	2,845	436	25,329	12.3	14.5	.990	9.3	10.7	9.80	2.47	
4	Dec. 15	4	10	14.8	70.7	39.17	1,086	3,697	539	32,524	12.0	14.1	.990	9.2	10.8	12.40	3.08	
5	Dec. 16	4	10	14.6	71.2	39.17	1,086	3,861	592	33,643	13.1	15.5	.992	8.9	10.5	13.24	3.19	
6	Dec. 20	4	10	14.9	71.5	39.17	1,086	3,147	420	28,681	10.8	12.4	.990	9.5	10.9	10.8	2.75	
7	Dec. 21	4	10	14.7	69.0	39.17	1,086	3,938	595	34,145	11.9	14.1	.990	9.0	10.7	13.5	3.30	
8	Dec. 23	4	10	14.8	68.7	39.17	1,086	4,114	703	37,091	11.3	13.6	.992	9.4	11.4	14.1	3.59	
	1888.																	
9	March 15	4	10	14.8	69.6	39.17	1,080	3,168	498	28,219	10.5	12.5	.985	9.3	11.0	10.9	2.70	
10	March 16	4	10	14.7	71.8	39.17	1,080	3,675	435	29,860	10.3	11.5	.989	8.6	9.7	12.6	3.00	
11	March 20	4	10	14.8	72.2	39.17	1,086	3,816	611	33,039	10.8	12.8	.994	8.8	10.5	13.1	3.12	
12	March 22	4	10	14.7	70.9	39.17	1,086	3,403	566	27,712	10.9	13.1	.978	8.6	10.4	11.7	2.70	
13	March 23	4	10	14.7	69.4	39.17	1,086	4,021	578	33,310	9.9	11.5	.975	8.5	10.0	14.8	3.17	
14	March 27	4	10.25	14.9	70.4	39.17	1,086	3,746	682	30,717	10.8	13.2	.978	8.5	10.4	12.5	2.87	
15	March 28	4	10	14.7	70.5	39.17	1,086	3,674	449	31,000	9.5	10.8	.974	8.7	9.9	12.6	2.90	
16	March 30	4	10	14.8	71.6	39.17	1,086	3,265	527	28,937	9.9	11.8	.977	8.5	10.1	11.2	2.33	
17	May 2	Shop.	10	14.9	36.4	13.50	930	1,057	203	8,945	14.3	17.7	.984	8.9	11.0	11.8	4.00	
18	May 3	Shop.	10.5	15.0	36.6	13.50	930	940	175	6,875	13.5	16.5	.985	8.8	10.5	7.6	2.61	
19	May 4	Shop.	10	14.9	36.2	13.50	930	896	188	6,758	13.0	22.1	.980	8.8	11.5	6.9	.86	
20	May 9	Shop.	10	14.8	36.2	13.50	930	894	169	6,332	18.7	23.7	.981	8.2	10.4	6.4	.78	
21	May 10	Shop.	10	14.8	36.0	13.50	930	874	165	5,930	20.7	25.6	.987	7.9	9.7	6.4	.74	
22	May 11	Shop.	10	14.8	36.0	13.50	930	914	252	6,516	15.9	22.0	.984	8.2	10.2	6.8	.81	
23	Dec. 12	B. & W.	10	14.6	72.3	51.3	2,214	7,567	1,053	62,073	13.6	15.6	.986	9.2	10.8	14.8	3.14	
24	Dec. 13	1	10	14.7	72.3	51.3	2,214	5,741	1,001	46,257	17.8	21.6	.970	8.9	10.8	11.2	3.33	
25	Dec. 14	1	10	14.7	62.7	51.3	2,214	6,337	1,401	53,258	14.6	16.6	.968	8.9	9.8	20.1	4.00	
26	Dec. 18	1	10.35	14.7	72.1	51.3	2,214	10,233	583	81,774	20.6	26.4	.976	9.6	10.5	10.5	2.87	
27	Dec. 19	1	10	14.7	72.3	51.3	2,214	5,643	385	45,148	24.6	28.4	.981	9.4	10.4	11.0	2.40	
28	Dec. 20	1	10	14.8	74.2	51.3	2,214	5,904	535	50,465	20.9	23.0	.981	9.5	10.4	11.5	2.52	
29	Dec. 21	1	10	14.7	73.8	51.3	2,214	5,761	374	51,524	22.4	24.0	.981	10.0	10.7	11.2	2.60	
	1889.																	
30	March 19	4	10	14.7	74.5	39.17	1,080	3,379	465	28,132	14.9	....	.987	8.8	10.2	11.6	2.74	9 tubes plugged.
31	March 20	4	11	14.7	74.6	39.17	988	3,622	441	29,745	14.1	16.1	.985	8.7	9.9	12.4	3.26	15 tubes plugged.
32	March 21	4	10	14.7	74.0	39.17	896	3,404	413	26,760	18.1	20.6	.979	8.7	9.4	11.7	3.20	25 tubes plugged.
33	March 22	4	10	14.9	75.0	39.17	740	3,485	438	27,212	15.7	18.0	.977	8.3	9.4	11.9	3.80	27 tubes plugged.
34	March 26	4	10	14.8	74.6	39.17	713	3,345	338	26,814	13.9	15.5	.988	8.7	9.7	11.1	3.06	17 tubes plugged.
35	March 27	4	10	14.8	75.2	39.17	849	3,502	353	29,001	14.0	16.2	.988	8.7	9.7	12.0	3.59	

BOILER TESTS. — *Concluded.*

Test number.	Date.	Boiler number. (Old numbering.)	Duration of test. (Hours.)	Pressure of air.	Average gauge pressure.	Grate area. (Square feet.)	Heating surface. (Square feet.)	Pounds of coal burned, including coal equivalent of wood.	Total refuse from coal.	Total water pumped into the boiler.	Air per pound of coal. (Pounds.)	Air per pound of combustible. (Pounds.)	Quality of steam.	Equivalent water evaporated into dry steam from and at 212° F. per pound of coal.	Equivalent water from and at 212° F. per pound of combustible.	Coal burned per sq. ft. of Grate per hour.	Water from and at 212° F. per sq. ft. heating surface per hour.	Remarks.
	1889.																	
36	March 28	4	10	14.7	75.6	29.17	836	3,167	337	24,586	14.4	16.2	.986	8.1	9.1	10.9	3.08	18 tubes plugged.
37	May 1	Shop.	10.25	14.7	61.4	15.7	862	952	134	6,569	15.1	17.6	.993	8.1	9.4	6.0	.90	5 tubes plugged.
38	May 2	Shop.	10	14.7	62.1	15.7	862	837	202	6,116	17.9	23.9	.992	8.6	11.3	5.3	.83	5 tubes plugged.
39	May 3	Shop.	10	14.7	62.1	15.7	862	885	127	6,265	22.4	26.1	.993	8.4	9.8	5.6	.86	5 tubes plugged.
40	May 7	Shop.	10	14.8	63.2	15.7	808	886	175	5,695	22.0	27.5	.991	7.6	9.5	5.6	.80	9 tubes plugged.
41	May 8	Shop.	10	14.8	57.6	15.7	786	772	153	5,768	58.0	73.0	.990	8.7	10.9	4.9	.71	11 tubes plugged.
42	May 9	Shop.	10	14.8	59.0	15.7	786	821	218	5,851	44.6	58.0	.989	8.3	11.3	5.2	.81	11 tubes plugged.
43	Dec. 10	B. & W.	10	15.0	71.1	51.3	2,214	6,779	1,015	53,452	11.9	14.1	.971	8.3	9.8	13.2	2.55	
44	Dec. 11	1	10	14.7	68.4	51.3	2,214	6,535	921	52,745	13.6	15.8	.983	8.7	10.1	12.7	2.55	
45	Dec. 12	1	10	14.7	65.6	51.3	2,214	7,198	1,200	54,397	13.0	15.6	.987	8.2	9.8	14.0	2.64	
46	Dec. 13	1	10	14.6	68.5	51.3	2,214	7,000	810	59,729	12.9	14.6	.987	9.2	10.4	13.6	2.88	
47	Dec. 16	1	10	14.9	68.0	51.3	2,214	7,744	971	62,753	10.9	12.5	.984	8.6	9.9	15.0	3.01	
48	Dec. 17	1	10	14.9	67.3	51.3	2,214	7,630	1,098	62,715	12.1	14.1	.984	8.9	10.4	14.8	3.07	
49	Dec. 19	1	10	15.0	66.8	51.3	2,214	8,493	1,260	65,162	....	....	.984	8.3	9.8	16.5	3.20	
50	Dec. 20	1	10	14.8	68.8	51.3	2,214	7,816	1,600	59,121	....	....	.981	8.2	10.3	15.3	2.89	
	1890.																	
51	March 18	1	10	14.6	71.7	51.3	2,214	8,417	1,176	70,121	12.9	15.0	.979	8.9	10.3	16.1	3.37	
52	March 19	1	10	14.6	70.7	51.3	2,214	10,075	1,544	80,351	13.2	15.7	.980	8.6	10.1	19.3	3.86	
53	March 20	1	10	14.8	72.0	51.3	2,214	8,364	1,471	71,215	12.6	15.1	.980	8.5	10.2	17.3	3.40	
54	March 21	1	10	14.6	70.8	51.3	2,214	7,671	1,119	62,501	14.4	16.8	.977	8.6	10.1	14.9	2.99	
55	March 26	1	10	14.9	73.2	51.3	2,214	6,031	1,031	52,686	16.0	19 3	.978	9.2	11.0	11.7	2.50	
56	March 27	1	10	14.8	72.5	51.3	2,214	8,032	1,325	66,531	12.5	14.9	.976	8.7	10.4	15.6	3.10	
57	Nov. 11	1	10	15.0	93.1	51.3	2,214	8,349	826	69,784	15.9	17.6	.992	9.5	10.5	16.3	3.66	
58	Nov. 12	1	10	15.0	102.1	51.3	2,214	8,091	650	66,140	12.7	....	.987	9.2	....	15.8	3.40	
59	Nov. 13	1	10	14.9	100.5	51.3	2,214	7,500	753	66,024	13.9	15.4	.985	9.9	11.0	14.6	3.40	
60	Nov. 14	1	10	14.8	101.5	51.3	2,214	6,434	753	55,677	14.3	....	.987	10.2	....	12.1	2.90	
61	Nov. 17	1	10	14.8	100.3	51.3	2,214	6,904	....	61,336	13.2	....	.986	10.1	....	13.5	3.10	
62	Nov. 18	1	10	14.6	101.0	51.3	2,214	6,600	....	57,648	11.9	....	.985	9.9	....	12.9	3.00	
63	Nov. 19	1	10	14.7	101.3	51.3	2,214	6,703	962	57,571	11.4	13.4	.985	9.6	11.2	13.1	2.90	
64	Nov. 20	1	10	14.7	98.2	51.3	2,214	7,800	1,025	69,986	15.4	17.8	.985	10.0	11.6	15.2	3.50	
65	Nov. 21	1	10	14.8	98.0	51.3	2,214	9,195	893	72,521	13.2	14.6	.986	8.9	9.8	17.9	3.70	
66	Nov. 24	1	10	14.9	96.1	51.3	2,214	8,700	1,116	77,401	11.1	12.7	.989	10.0	11.5	17.0	3.90	
67	Nov. 25	1	10	14.7	101.0	51.3	2,214	7,500	864	65,345	11.9	13.4	.986	10.0	11.3	14.6	3.40	

SUMMARY OF A 72-HOUR BOILER TEST. March 9 to March 12, 1891.

Time.	Pressures.		Temperatures.	Weights.				Results of calorimeter experiments.	Ashes and clinkers.
	Barometer, pounds per square inch.	Steam gauge.	Feed. °C.	Pounds of water. Boiler No. 3.	Pounds of fuel. Boiler No. 3.	Left door. Average pounds of air for 15 min. Boiler No. 3.	Right door. Average pounds of air for 15 min. Boiler No. 3.		
March 9									
4–12	14.8	143.6	54.5	37,174	4,800	1,204	945	....	492
March 10									
12–8	14.7	145.1	64.7	31,550	3,000	940	818	.978	430
8–4	14.9	141.0	48.9	48,255	5,700	1,615	1,294	.976	544
4–12	14.9	141.9	45.1	25,807	4,200	1,202	929	.975	660
March 11									
12–8	15.0	143.6	57.9	28,856	2,400	937	746	.975	519
8–4	15.0	141.5	52.7	32,453	4,500	1,035	881	.974	702
4–12	15.0	144.3	63.6	31,956	4,500	1,043	831	.975	430
March 12									
12–8	14.8	144.8	64.6	33,500	2,700	1,195	888	.975	477
8–4	14.9	141.6	61.9	41,564	5,700	1,912	1,515	.974	816
Total . .				311,115	37,500				5,070
Average .	14.9	143.0	57.1					.975	

		Boiler No. 3.
1.	Description of boilers: Babcock & Wilcox. 108 tubes, 4 inches diameter, 17 feet 8 inches long, outside area = 1997.3 square feet. 12 tubes, 4 inches diameter, 4 feet 6 inches long, outside area = 56.5 square feet. 2 drums, 3 feet diameter, 17 feet long, ½ outside area = 160.2 square feet.	
2.	Grate surface, No. 3, 84 inches by 88 inches area, square feet	51.3
3.	Water-heating surface, square feet	2,214
4.	Ratio of water-heating surface to grate surface	43.16
5.	Pounds of coal fired, including coal equivalent of wood	37,500
6.	Unburned fuel	....
7.	Coal burned, including coal equivalent of wood	37,500
8.	Average coal burned for 15 minutes	130.2
9.	Total refuse from coal	5,070
10.	Total combustible	32,430
11.	Average combustible for 15 minutes	112.6
12.	Average pounds of air for 15 minutes	2,214
13.	Air per pound of coal	17.0
14.	Air per pound of combustible	19.0
15.	Quality of steam, saturated steam taken as unity	.975
16.	Total water pumped into boiler and apparently evaporated	311,115
17.	Water apparently evaporated per pound of coal	8.3
18.	Water actually evaporated, corrected for quality of steam	303,337
19.	Equivalent water evaporated into dry steam, from and at 212° F.	344,018
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal,	9.17
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.61
22.	Coal burned per square foot of grate surface per hour	10.2
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	2.16

SUMMARY OF A 128-HOUR BOILER TEST. December 28, 1891, to January 2, 1892.

Time.	Pressures.		Temperatures.				Weights.				Results of calorimeter experiments.	Ashes and clinkers.
	Barometer, pounds per square inch.	Steam gauge.	Outside air. °F.	East door air. Boiler No. 1.	West door air. Boiler No. 1.	Feed. °C.	Pounds of water. Boiler No. 1.	Pounds of fuel. Boiler No. 1.	Average pounds of air for 15 minutes. Boiler No. 1, east door.	Average pounds of air for 15 minutes. Boiler No. 1, west door.		
1891.												
Dec. 28												
7-3	14.94	107.5	36.5	58	60	42.15	41,330	4,800	857	1,106	.984	884
3-11	15.02	109.2	35.3	68	68	37.96	32,202	3,610	620	915	.984	706
11-7	15.01	105.4	30.4	67	67	56.04	39,111	4,500	1,050	1,445	.983	522
Dec. 29												
7-3	14.94	109.1	42.0	67	67	54.10	35,423	4,300	701	909	.983	4,535
3-11	14.79	107.6	47.0	70	70	47.20	33,928	4,200	838	921	.984	735
11-7	14.64	109.2	50.0	68	71	49.77	32,541	3,000	715	715	.983	401
Dec. 30												
7-3	14.58	108.4	42.1	.	69	53.12	29,207	3,900	Closed.	1,486	.983	471
3-11	14.74	108.9	36.0	66	66	54.10	30,695	4,200	613	746	.983	456
11-7	14.85	102.8	21.5	52	54	50.52	38,925	3,900	864	953	.982	311
Dec. 31												
7-3	14.92	107.9	....	..	60	56.12	49,758	6,600	Closed.	2,475	.982	1,121
3-11	14.98	106.7	28.0	56	53	46.00	32,848	4,200	598	774	.982	628
11-7	15.00	108.3	26.5	68	67	59.90	33,826	3,329	708	735	.982	593
1892.												
Jan. 1												
7-3	14.98	135.0	36.6	61	62	51.96	31,322	4,200	730	786	.981	515
3-11	14.89	117.1	37.0	62	62	48.77	29,801	3,300	575	661	.982	343
11-7	14.80	110.2	40.7	66	66	56.10	28,715	3,600	1,027	1,008	.982	242
Jan. 2												
7-3	14.70	104.8	52.3	66	66	44.41	29,162	3,000	646	724	.982	288
Total . .							548,794	64,639				8669.5
Average .	14.85	109.9	37.5	64.0	64.0	50.51			1,681		.983	

		Boiler No. 1.
1.	Description of Boilers: Babcock & Wilcox No. 1. 108 tubes, 4 inches diameter, 17 feet 8 inches long, outside area = 1997.3 square feet. 12 tubes, 4 inches diameter, 4 feet 6 inches long, outside area = 56.5 square feet. 2 drums, 3 feet diameter, 17 feet long, ½ of outside surface = 160.2 square feet.	
2.	Grate surface, No. 1, 84 inches by 88 inches area, square feet	51.3
3.	Water-heating surface, square feet	2,214
4.	Ratio of water-heating surface to grate surface	43.16
5.	Pounds of coal fired, including coal equivalent of wood	64,639
6.	Unburned fuel	....
7.	Coal burned, including coal equivalent of wood	64,639
8.	Average coal burned for 15 minutes	126.2
9.	Total refuse from coal	8,669
10.	Total combustible	55,970
11.	Average combustible for 15 minutes	109.3
12.	Average pounds of air for 15 minutes	1,681
13.	Air per pound of coal	13.32
14.	Air per pound of combustible	15.38
15.	Quality of steam, saturated steam taken as unity	.983
16.	Total water pumped into boiler and apparently evaporated	548,794
17.	Water apparently evaporated per pound of coal	8.49
18.	Water actually evaporated, corrected for quality of steam	539,465
19.	Equivalent water evaporated into dry steam, from and at 212° F.	614,277
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	9.50
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.98
22.	Coal burned per square foot of grate surface per hour	9.84
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	2.167

SUMMARY OF A 56-HOUR BOILER TEST ON A BATTERY OF TWO 208 H. P. BABCOCK & WILCOX BOILERS. April 13, 14, 15, 1892.

Time.	Pressures.		Temperatures.					Weights.					Results of calorimeter experiments.	Ashes.	
	Barometer, pounds per square inch.	Steam gauge.	Outside air. °F.	Air. Boiler No. 1.	Air. Boiler No. 3.	Feed 1. °C.	Feed 3. °C.	Pounds of water. Boilers Nos. 1 & 3.	Pounds of fuel. Boiler No. 1.	Pounds of fuel. Boiler No. 3.	Average pounds of air for 15 minutes. Boiler No. 1.	Average pounds of air for 15 minutes. Boiler No. 3.		Number 1.	Number 3.
1892.															
April 13															
8–4	14.80	113.5	53	58	59	39.4	39.3	70,616	3,900	3,600	1,868	2,247	.986	215	340
4–12	14.84	116.2	47	49	49	35.6	35.2	62,095	2,700	3,300	1,997	1,937	.986	739	...
April 14															
12–8	14.80	107.1	39	41	42	25.7	25.9	41,592	3,900	3,300	2,203	1,946	.986	375	724
8–4	14.85	126.1	50	55	58	41.5	42.9	80,839	3,900	5,400	1,774	2,403	.985	276	700
4–12	14.80	118.4	50	58	59	47.2	48.9	45,384	3,000	3,000	1,482	1,211	.986	639	...
April 15															
12–8	14.73	122.3	43	68	67	57.0	60.2	35,575	2,400	1,500	1,038	913	.986	347	602
8–4	14.71	121.6	47	69	61	44.9	46.3	76,870	3,900	4,500	1,965	1,869	.986	239	275
Total . .								412,971	23,700	24,600				2,830	2,641
Average .	14.80	117.9				41.6	42.7				1,761	1,789	.986		

		Boiler No. 1.	Boiler No. 3.
1.	Description of Boilers: 2 Babcock & Wilcox, run in battery.		
2.	Grate surface, { No. 1, 84 inches by 88 inches area, square feet / No. 3, 84 inches by 88 inches area, square feet }	51.3	51.3
3.	Water-heating surface, square feet	2,214	2,214
4.	Ratio of water-heating surface to grate surface	43.16	43.16
5.	Pounds of coal fired, including coal equivalent of wood	23,700	24,600
6.	Unburned fuel	....	....
7.	Coal burned, including coal equivalent of wood	23,700	24,600
8.	Average coal burned for 15 minutes	105.8	109.8
9.	Total refuse from coal	2,830	2,641
10.	Total combustible	20,870	24,600
11.	Average combustible for 15 minutes	93.1	98.0
12.	Average pounds of air for 15 minutes	17.61	17.89
13.	Air per pound of coal	16.6	16.3
14.	Air per pound of combustible	18.9	18.3
15.	Quality of steam, saturated steam taken as unity	.986	
16.	Total water pumped into boiler and apparently evaporated	412,971	
17.	Water apparently evaporated per pound of coal	8.55	
18.	Water actually evaporated, corrected for quality of steam	407,189	
19.	Equivalent water evaporated into dry steam, from and at 212° F.	470,449	
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	9.74	
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.98	
22.	Coal burned per square foot of grate surface per hour	8.25	8.56
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	1.89	

AVERAGE TEMPERATURE °C. BY PYROMETER.

	Beyond and near top of first baffle plate.	Beyond and at the bottom of first baffle plate.	In the flue 14 feet above grate.
1st 8 hours . . .	636	310	230
2d 8 hours . . .	610	325	227
3d 8 hours . . .	433	260	206
4th 8 hours . . .	737	339	277
5th 8 hours . . .	470	248	162
6th 8 hours . . .	452	232	152
7th 8 hours . . .	...	...	...

Pyrometer readings, samples of flue gas, and draught pressures were taken at frequent intervals from different parts of the setting and from the flue of boiler No. 3.

AVERAGE DRAUGHT PRESSURE IN INCHES OF WATER AT 22° C.

Ash-pit.	Over grate.	Flue 14 feet above grate.
.042	.094	.475

ANALYSIS OF COAL AND ASH.

	C.	H.	H_2O.	S.	Ash.	N and O.
Coal	83.07	2.69	2.07	0.80	8.86	2.51
Ash	2.75	.13	0.	....	....	....

SUMMARY OF A 128-HOUR BOILER TEST ON NO. 3 BOILER.
January 2–7, 1893.

Time.	Pressures.		Temperatures.		Weights.			Results of calorimeter experiments.	Refuse from coal.
	Barometer, pounds per square inch.	Steam gauge.	Outside air. °F.	Feed. °C.	Pounds of water. Boiler No. 3.	Pounds of fuel. Boiler No. 3.	Average pounds of air for 15 minutes. Boiler No. 3.		
1893.									
Jan. 2									
8–4	14.5	111.7	44.0	42.7	44,406.0	5,100	1,675	....	383.0
4–12	14.6	114.9	36.0	40.5	37,884.5	4,500	1,483	....	215.0
Jan. 3									
12–8	14.6	113.4	30.0	42.8	35,222.0	4,200	1,817	.984	327.0
8–4	14.7	110.2	29.5	45.6	38,067.0	5,400	1,903	.986	1297.0
4–12	14.7	110.4	15.5	43.1	44,887.0	5,700	1,941	.987	698.5
Jan. 4									
12–8	14.8	110.0	8.0	48.4	43,468.0	5,400	1,869	.986	375.0
8–4	14.7	86.1	14.7	42.8	49,627.0	6,282	1,812	.989	887.5
4–12	14.7	107.9	14.7	44.6	35,079.0	4,250	1,983	.985	670.0
Jan. 5									
12–8	14.7	106.9	17.0	47.5	41,958.0	5,100	2,282	.986	525.0
8–4	14.7	102.6	24.0	43.3	49,613.0	6,600	2,306	.987	1039.0
4–12	14.7	109.0	20.0	44.8	32,391.0	3,900	1,833	.986	571.0
Jan. 6									
12–8	14.7	105.9	10.8	54.8	42,073.0	5,700	2,351	.987	445.0
8–4	14.6	77.2	12.9	40.0	49,774.0	6,900	2,495	.984	921.0
4–12	14.6	96.9	11.0	38.8	36,525.0	4,500	2,348	.985	486.0
Jan. 7									
12–8	14.7	98.1	8.0	34.2	40,503.0	6,000	2,628	.984	682.0
8–4	14.8	96.0	18.7	41.1	40,734.0	6,300	2,837	.983	1335.5
Total . .	....	....	....	....	662,212	85,832			10,857.5
Average .	14.7	103.6	19.7	43.44			2,098	.986	

		Boiler No. 3.
1.	Description of boilers: Babcock & Wilcox, water tube.	
2.	Grate surface, No. 3, 84 inches by 88 inches area, square feet	51.3
3.	Water-heating surface, square feet	2,214
4.	Ratio of water-heating surface to grate surface	43.16
5.	Pounds of coal fired, including coal equivalent of wood	85,832
6.	Unburned fuel	....
7.	Coal burned, including coal equivalent of wood	85,832
8.	Average coal burned for 15 minutes	167.64
9.	Total refuse from coal	10,858
10.	Total combustible	74,974
11.	Average combustible for 15 minutes	146.43
12.	Average pounds of air for 15 minutes	2,098
13.	Air per pound of coal	12.52
14.	Air per pound of combustible	14.33
15.	Quality of steam, saturated steam taken as unity	.986
16.	Total water pumped into boiler and apparently evaporated	662,212
17.	Water apparently evaporated per pound of coal	7.72
18.	Water actually evaporated, corrected for quality of steam	652,940
19.	Equivalent water evaporated into dry steam, from and at 212° F.	750,970
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	8.75
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.02
22.	Coal burned per square foot of grate surface per hour	13.07
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	2.65

SUMMARY OF A 54-HOUR BOILER TEST. April 10, 11, 12, 1893.

Time.	Pressures.	Temperatures.		Weights.				Results of calorimeter experiments.	Ashes and clinkers.
	Absolute boiler pressure.	Outside air. °F.	Feed. °C.	Pounds of water. Boiler No. 3.	Pounds of fuel. Boiler No. 3.	Average pounds of air for 15 minutes. Boiler No. 3, right door.	Average pounds of air for 15 minutes. Boiler No. 3, left door.		
1893.									
April 10.									
7.15–1	130.8	45.6	28.44	34,052	3,900	954	1,142	.977	493.5
7–1	128.2	39.8	31.20	34,707	3,300	744	854	.972	530.0
1–7	145.5	44.0	29.84	29,447	3,300	566	637	.973	150.0
April 11.									
1–7	127.8	37.0	31.90	25,938	3,900	1,103	1,103	.974	400
7–1	131.5	51.3	31.60	34,056	5,700	706	870	.973	852
1–7	141.5	53.0	31.10	36,044	3,600	752	895	.973	255
7–1	138.8	43 0	34.60	33,400	3,900	865	1,035	.980	275
April 12.									
1–7	131.9	37.3	40.6	30,198	4,200	874	1,079	.972	1,001
7–1.15	128.7	56.0	33.80	31,364	3,900	811	712	.972	424
Total . . .				289,204	35,700				4,382
Average . .	135.7		32.56			1,745		.974	

		Boiler No. 3.
1.	Description of boilers: Babcock & Wilcox.	
2.	Grate surface, No. 3, 84 inches by 88 inches area, square feet	51.3
3.	Water-heating surface, square feet	2,214
4.	Ratio of water-heating surface to grate surface	43.16
5.	Pounds of coal fired, including coal equivalent of wood	35,700
6.	Unburned fuel	....
7.	Coal burned, including coal equivalent of wood	35,700
8.	Average coal burned for 15 minutes	165.3
9.	Total refuse from coal	4,382
10.	Total combustible	31,318
11.	Average combustible for 15 minutes	145
12.	Average pounds of air for 15 minutes	1,745
13.	Air per pound of coal	10.56
14.	Air per pound of combustible	12.04
15.	Quality of steam, saturated steam taken as unity	.974
16.	Total water pumped into boiler and apparently evaporated	289,204
17.	Water apparently evaporated per pound of coal	8.1
18.	Water actually evaporated, corrected for quality of steam	281,685
19.	Equivalent water evaporated into dry steam, from and at 212° F.	331,687
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	9.29
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.59
22.	Coal burned per square foot of grate surface per hour	12.88
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	2.77

SUMMARY OF AN 88-HOUR BOILER TEST. December 26–30, 1893.

Time.	Pressures.		Temperatures.		Weights.			Results of calorimeter experiments.	Draught in Inches of Water.	
	Barometer, pounds per square inch.	Steam gauge.	Outside air. °F.	Feed. °C.	Pounds of water. Boiler No. 3.	Pounds of fuel. Boiler No. 3.	Average pounds of air for 15 minutes. Boiler No. 3.		Ash-pit.	Flue.
1893.										
Dec. 26										
4–12	14.9	109.4	21.5	41.02	44,968	5,700	2,385	.985	.0264	.4664
Dec. 27										
12–8	14.9	104.3	20.3	44.72	45,491	7,800	2,322	.983	.0353	.6340
8–4	14.8	110.8	31.5	41.03	44,774	7,500	1,303	.982	.0380	.6370
4–12	14.7	108.6	28.9	42.98	40,811	5,100	1,930	.984	.0390	.5690
Dec. 28										
12–8	14.7	108.5	30 6	31.99	40,428	5,700	1,834	.984	.0440	.5580
8–4	14.6	114.6	37.1	45.90	45,637	6,000	1,683	.983	.0177	.5630
4–12	14.5	112.9	40.7	45.80	39,672	5,100	1,636	.982	.0402	.5030
Dec. 29										
12–8	14.5	113.5	43.2	36.48	36,493	5,700	1,947	.984	.0376	.4750
8–4	14.5	114.3	46.4	38.82	35,690	4,500	....	.984	.0220	.4840
4–12	14.6	113.0	41.0	43.20	38,921	4,500	2,170	.984	.0348	.5290
Dec. 30										
12–8	14.7	100.7	34.2	48.80	39,410	6,300	2,749	.984	.0263	.6180
Total . .					452,295	63,900				
Average .	14.7	110.1	34.1	41.89			1,996	.984	.0328	.5488

		Boiler No. 3.
1.	Description of boilers: Babcock & Wilcox.	
2.	Grate surface, No. 3, 84 inches by 88 inches area, square feet	51.3
3.	Water-heating surface, square feet	2,214
4.	Ratio of water-heating surface to grate surface	43.16
5.	Pounds of coal fired, including coal equivalent of wood	63,900
6.	Unburned fuel	....
7.	Coal burned, including coal equivalent of wood	63,900
8.	Average coal burned for 15 minutes	181.5
9.	Total refuse from coal	10,113
10.	Total combustible	53,787
11.	Average combustible for 15 minutes	152.8
12.	Average pounds of air for 15 minutes	1,996
13.	Air per pound of coal	10.99
14.	Air per pound of combustible	13.06
15.	Quality of steam, saturated steam taken as unity	.984
16.	Total water pumped into boiler and apparently evaporated	452,295
17.	Water apparently evaporated per pound of coal	7.08
18.	Water actually evaporated, corrected for quality of steam	445,058
19.	Equivalent water evaporated into dry steam, from and at 212° F.	514,065
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	8.04
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	9.56
22.	Coal burned per square foot of grate surface per hour	14.16
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	2.64

SUMMARY OF A 60-HOUR TEST ON BATTERY OF 2 208 H. P. BABCOCK & WILCOX BOILERS. April 24–26, 1894.

Time.	Pressures. Barometer, pounds per square inch.	Pressures. Steam gauge.	Temperatures. Outside air. °C.	Temperatures. Feed. °C. Boiler No. 1.	Temperatures. Feed. Boiler No. 3.	Weights. Pounds of water. Boilers Nos. 1 & 3.	Weights. Pounds of fuel. Boiler No. 1.	Weights. Pounds of fuel. Boiler No. 3.	Weights. Average pounds of air for 15 minutes. Boiler No. 1.	Weights. Average pounds of air for 15 minutes. Boiler No. 3.	Results of calorimeter experiments.	Ashes. No. 1.	Ashes. No. 3.	Average Draught of Gauge in Flue. No. 1.	Average Draught of Gauge in Flue. No. 3.	Temperature of Flue. °C. No. 1.	Temperature of Flue. °C. No. 3.
1894.																	
April 24																	
7–1	14.7	121.5	17.0	36.6	37.2	49,214	2,400	2,400	1,231	1,337	.987	....	....	.480	.467	188	193.7
1–7	14.7	122.1	16.6	40.9	41.5	56,821	2,100	3,000	3,059	1,394	.984	1,054	158	.421	.426	242	203
7–1	14.7	121.3	11.8	33.6	41.9	11,991	....	600	....	....	.987	....	51	.366	.361	147	160
April 25																	
1–7	14.8	114.2	7.9	31.2	32.7	11,266	2,100	2,400	....	....	.988	....	663	.369	.382	135	166
7–1	14.8	120.9	14.5	41.4	42.1	50,630	1,475	2,975	1,089	1,548	.987	....	....	.472	.486	192	205
1–7	14.8	119.5	20.0	42.2	43.4	43,832	2,100	2,700	1,429	945	.987	735	152	.502	.514	192	199
7–1	14.8	115.0	11.2	33.4	49.9	13,433	....	900	....	....	.993	....	115	.349	.390	133	....
April 26																	
1–7	14.8	106.2	9.6	....	37.1	10,811	1,500	2,700	....	....	.988	....	874	.355	.397	133	....
7–1	14.8	117.1	19.8	41.1	30.8	53,393	2,700	4,200	1,750	1,613	....	....	....	.467	.483	196	234
1–7	14.8	121.5	25.0	36.9	41.5	54,271	1,800	2,400	1,690	1,421	....	80	243	.531	.483	217	223
Total . .						355,662	16,175	24,275				1,869	2,256				
Average .	14.8	117.9		35.7	39.8				1,700	1,400	.988						

1.	Description of boilers: Babcock & Wilcox battery of 2 208 H. P. boilers.	
2.	Grate surface, { No. 1, 84 inches by 88 inches area, square feet / No. 3, 84 inches by 88 inches area, square feet }	102.6
3.	Water-heating surface, square feet	4,428
4.	Ratio of water-heating surface to grate surface	43.15
5.	Pounds of coal fired, including coal equivalent of wood	40,450
6.	Unburned fuel	....
7.	Coal burned, including coal equivalent of wood	40,450
8.	Average coal burned for 15 minutes	168.54
9.	Total refuse from coal	4,125
10.	Total combustible	36,325
11.	Average combustible for 15 minutes	151.35
12.	Average pounds of air for 15 minutes	3,100
13.	Air per pound of coal	18.4
14.	Air per pound of combustible	20.48
15.	Quality of steam, saturated steam taken as unity	.988
16.	Total water pumped into boiler and apparently evaporated	355,662
17.	Water apparently evaporated per pound of coal	8.8
18.	Water actually evaporated, corrected for quality of steam	351,432
19.	Equivalent water evaporated into dry steam, from and at 212° F.	408,545
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	10.1
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	11.25
22.	Coal burned per square foot of grate surface per hour	6.57
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	1.54

Note. — Fire of boiler No. 1 was banked every night, and the test made on the boilers as they were run ordinarily.

TESTS ON A NO. 6 DOUGLAS HYDRAULIC RAM.

Number of test.	Date.	Head on ram.	Delivery pressure.	Weight delivered.	Pulses per minute.	Water fed per minute.	Water delivered per minute.	Available work per minute.	Work done per minute.	Efficiency.	Capacity in gallons per minute.
	1893.										
1	Dec. 24	12′.4	26.0	320	100	225	21.0	2,785	1,279	45.9	2.85
2	Dec. 15	....	26.0	307	101	230	24.7	2,847	1,500	52.7	3.30
3	Dec. 13	....	27.0	260	98	217	17.3	2,687	1,079	40.2	2.31
	1894.										
4	Feb. 1	....	19.0	246	84	201	18.9	2,487	829	33.3	2.30
6	Feb. 2	....	20.4	344	86	178	22.9	2,207	1,079	48.9	2.3
7	Feb. 2	....	23.7	195	83	153	13.0	1,895	712	37.6	1.6
8	Feb. 5	....	24.1	279	87	163	9.3	2,019	518	25.6	1.1
9	Feb. 5	....	25.3	328	84	150	10.9	1,859	639	34.4	1.3
10	Feb. 6	....	20.7	591	88	177	19.7	2,196	942	42.8	2.37
11	Feb. 6	....	22.5	452	84	158	15.1	1,960	783	39.9	1.81
12	Feb. 7	....	22.0	269	86	168	17.9	2,083	932	44.7	2.15
13	Feb. 8	....	22.8	415	85	166	13.8	2,055	728	35.4	1.66
14	Feb. 8	....	23.5	410	86	164	13.7	2,031	744	36.6	1.65
15	Feb. 9	....	23.5	260	87	168	13.0	2,083	706	33.9	1.56
16	Feb. 9	....	21.2	426	86	172	21.3	2,130	1,043	49.0	2.56
18	Feb. 12	....	13.2	1,702	83	217	56.7	2,685	1,729	64.5	6.81
19	Feb. 12	....	14.5	645	87	207	43.0	2,567	1,440	56.1	5.16
20	Feb. 13	....	12.7	830	85	214	55.3	2,654	1,623	61.2	6.64
21	Feb. 14	....	20.5	676	86	179	22.5	2,214	1,039	46.9	2.70
22	Feb. 15	....	18.6	547	87	186	27.4	2,303	1,175	51.0	3.28
23	Feb. 15	....	18.2	580	88	193	29.0	2,393	1,219	50.9	3.48
24	Feb. 16	....	17.0	732	87	197	36.6	2,447	1,439	59.0	4.39
25	Feb. 16	....	19.4	521	86	192	34.7	2,380	1,555	65.0	4.16
26	Feb. 19	....	18.0	610	86	192	30.5	2,377	1,268	53.3	3.66
27	Feb. 20	....	18.0	570	88	191	28.5	2,369	1,185	50.0	3.42
28	Feb. 20	....	17.7	431	86	189	28.7	2,337	1,173	50.2	3.45
29	Feb. 23	....	19.5	378	90	188	25.2	2,325	1,135	48.8	3.03
30	Feb. 26	....	17.7	437	86	190	29.1	2,358	1,189	50.4	3.50
31	Feb. 27	....	18.3	451	87	190	30.0	2,360	1,270	53.8	3.60
32	March 1	....	19.5	498	88	185	24.9	2,288	1,121	49.0	2.99
33	March 1	....	18.3	432	89	193	29.0	2,392	1,217	50.9	3.46
34	March 2	....	19.5	365	88	187	24.3	2,316	1,096	47.3	2.92
35	March 2	....	20.0	508	90	187	25.4	2,323	1,173	50.5	3.05
36	March 5	....	20.3	350	89	190	23.3	2,360	1,092	46.3	2.79
37	March 6	....	20.2	363	87	184	24.2	2,279	1,124	49.3	2.90
38	March 9	....	13.2	995	86	240	66.3	2,980	2,020	67.9	7.96
39	March 9	....	17.2	488	86	210	32.5	2,610	1,230	49.6	3.90
40	March 12	....	17.4	471	86	207	31.4	2,570	1,260	49.2	3.77
41	March 13	....	22.1	256	93	187	17.1	2,320	873	37.6	2.06
42	March 13	....	21.9	253	90	187	16.8	2,320	850	36.7	2.01

A COMPARISON OF THE DISSOCIATION VALUES CALCULATED FROM SOLUBILITY EXPERIMENTS AND FROM THE ELECTRICAL CONDUCTIVITY.

By ARTHUR A. NOYES and CHARLES G. ABBOT.

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CONTENTS. — 1. Aim and principle of the investigation. 2. Preparation and analysis of the salts. 3. Methods of procedure. 4. The experimental results. 5. Calculation of the dissociation. 6. The validity of the solubility principles. 7. The electrical conductivity of the salts and the values of the dissociation calculated therefrom. 8. The agreement of the dissociation values obtained by the two methods.

1. The Aim and Principle of the Investigation.

The application of the law of chemical mass-action to the case of saturated solutions of partially dissociated salts leads to the following principle, which was first expressed by Nernst: The product of the masses of the ions of the salt with which the solution is saturated remains constant in the presence of other salts. The exactness of this principle is, however, not as yet thoroughly established. It is doubtful whether the law of mass-action may properly be applied to this case, since the dissociation of salts as derived from electrical conductivity measurements does not vary with the concentration of the solution in accordance with the requirements of that law. Moreover, experimental investigation of the Nernst principle has not led to decisive results. The first experiments relative to this principle were conducted by Nernst[1] and by one of the present authors.[2] The solubility of a difficultly soluble salt was determined both in pure water and in the presence of other soluble salts, which had an ion in common with the first. The solubility of the difficultly soluble salt in the presence of the added salt was also calculated, with the help of the Nernst principle, from the values of the dissociation obtained by means of electrical conductivity measurements. The agreement between the observed and calculated solubility values was only approx-

[1] Zeitschrift für physikalische Chemie, **4**, 372. [2] Ibid., **6**, 241.

imate. It was, however, uncertain whether the cause of this deviation lay in the failure of the Nernst principle or in the inaccuracy of the dissociation values calculated under the assumption that the electrical conductivity of salts is exactly proportional to their dissociation. Later Arrhenius[1] made similar solubility measurements, and calculated the dissociation of the difficultly soluble salt by means of the Nernst principle without the help of electrical conductivity measurements. Obtaining disagreeing values from different series of experiments, he concluded that the solubility principle is incorrect. But his calculations involved the assumption that the dissociation of the saturating salt is the same as that of the added salt, which assumption is certainly groundless, so that his experiments do nothing to settle the question of the validity of the solubility principle. Recently the results of Goodwin[2] have lent indirect support to the principle; for he shows that other methods (namely, the electromotive force and the conductivity method) lead to the same values of dissociation as the application of the Nernst principle itself. On account of the great importance of the applications of this principle a direct analytical proof of its accuracy is very desirable.

It was the aim of our experiments to make such a test by a method which requires no other data than the following: (A) Experimentally derived solubility values. (B) The principles of solubility,[3] which may be stated as follows: 1. In a saturated solution of a salt the absolute amount of the undissociated part remains constant even in the presence of other salts. 2. The product of the masses of the ions of the salt also remains constant.

So long as the effect of a soluble salt on the solubility of a difficultly soluble one is investigated some further assumption is necessary for the calculation of the dissociation of the latter. If, however, two salts are taken which are both in saturated solution, and the effect of each in diminishing the solubility of the other is measured, then the two foregoing principles enable us to calculate the dissociation of each. By investigating three salts in pairs two independent check-results may be obtained on the dissociation of each salt, and the validity of the solubility principles may be judged of by the closeness of their agreement. The theory of this method will

[1] Zeitschrift für physikalische Chemie, 11, 391.

[2] Zeitschrift für physikalische Chemie, 13, 613. [3] Ibid., 9, 603.

be better understood after inspection of the following mathematical formulæ. Let m_0 and m_0' be the solubilities of two salts in pure water; m and m', their solubilities when botn salts are present in excess; and a_0, a_0', a, and a', the corresponding values of their dissociations. Then as the expression of the first solubility principle (namely, the undissociated part remains constant) we have the following equations:

$$m_0 (1 - a_0) = m (1 - a), \qquad (1)$$
$$m_0' (1 - a_0') = m' (1 - a'); \qquad (2)$$

and as the expression of the second solubility principle (namely, the product of the masses of the ions remains constant), the following:

$$m_0^2 a_0^2 = ma (ma + m'a'), \qquad (3)$$
$$m_0'^2 a_0'^2 = m'a' (ma + m'a'). \qquad (4)$$

These four equations contain only four unknown quantities, the four values of the dissociations, and can readily be solved. For the purpose of comparison it is necessary to solve for a_0. The value of the dissociation of each salt may then be calculated for its saturated solution in pure water, from the results of solubility measurements with it in presence of the other two salts separately. From the closeness of the agreement of the three resulting pairs of checks the correctness of the solubility principles may be ascertained.

It was first necessary to find three suitable salts. Such salts must fulfil two conditions: First, their solubilities must not be very different, else the influence of the more difficultly soluble salt upon the solubility of the others will be too slight for accurate determination. Second, there must be trustworthy methods of analysis for the determination of each salt alone and in the presence of each of the others. The chloride, sulphocyanate, and bromate of thallium were found to satisfy these requirements perfectly. Their solubilities at the temperature chosen for these experiments were, respectively, 0.025, 0.028, and 0.022 normal in round numbers, and their analysis presented no particular difficulties. These three salts were combined in three pairs, and for each pair the solubility of each salt was determined in a solution in which both salts were present in excess.

2. Preparation and Analysis of the Salts.

The salts were all prepared from metallic thallium. The metal was dissolved in moderately concentrated sulphuric acid, the solution

somewhat diluted and filtered, and a part of the thallous sulphate allowed to crystallize out. This salt was washed until free from acid, and its solution was precipitated with potassium bromate. It is of the utmost importance that the solution should be neutral, otherwise the thallium is oxidized at the expense of the bromate, so that an impure product results. The precipitated thallous bromate was washed thoroughly and then recrystallized from hot water. The chloride and sulphocyanate were prepared from the mother-liquor of the thallous sulphate by precipitation with hydrochloric acid and with potassium sulphocyanate, respectively. Both precipitates were washed thoroughly and afterwards recrystallized from hot water.

The purity of the three salts was established by test analyses. This precaution was especially necessary in the case of the bromate, owing to the readiness with which this salt is oxidized. The analyses gave the following results:

TlCl: Per cent. Cl.		TlSCN: Per cent. SCN.		$TlBrO_3$: Per cent. Br.	
Calculated.	Found.	Calculated.	Found.	Calculated.	Found.
14.80	14.81	22.16	22.24	24.07	24.11
....	14.86	....	22.21	....	24.10

3. The Methods of Procedure.

Bottles of about 150 cc. capacity were nearly filled with water, and an excess (about 2 grams) of the salt or salts to be investigated was added. In order to approach the condition of saturation from each side cold water and hot water were used alternately in the preparation of successive solutions. The bath, with rotating apparatus, in which the solutions were brought to the condition of saturation, has already been described.[1] The solubilities of the three salts used in this investigation are such that 40° C. (39.75° corrected) was chosen as a suitable temperature for the experiments; and the bath was maintained within 0.03° C. of that temperature by means of an Ostwald regulator. The solutions were rotated in the bath from three to four hours, and were then allowed to settle. After they became quite clear 100 cc. portions (measured at 40°) were blown out into graduated

[1] Zeitschrift für physikalische Chemie, 9, 606.

flasks by means of a wash-bottle arrangement; and these portions were analyzed by the methods to be now described:

All the analyses were made in the gravimetric way, with Gooch crucibles. In experiments where chloride or sulphocyanate was alone present the corresponding silver salt was precipitated by the addition of an excess of silver nitrate to the hot neutral solution. The same process served for the determination of the sum of the chloride and sulphocyanate when both were present together, and also for the determination of chloride or sulphocyanate in the presence of bromate. In these two latter cases, however, it was very important that the solution should be hot and dilute before the addition of silver nitrate, otherwise silver bromate was precipitated at the same time with the other silver salt. We determined the solubility of the bromate in pure water by the addition, in succession, of an excess of sulphurous acid, about 20 cc. nitric acid (1.20 sp. gr.), and an excess of silver nitrate to the hot and dilute solution. In the presence of the other salts the bromate was determined in the filtrate after precipitation of the chloride or sulphocyanate by the addition first of nitric acid and then of an excess of sulphurous acid and of silver nitrate to the hot solution. The most difficult analytical problem was to determine the chloride in the presence of sulphocyanate. After testing with unfavorable results several processes which depended on the oxidation of the sulphocyanate to sulphate, and precipitation of the latter with barium salts, we had recourse to a method for separation of chloride and sulphocyanate based on the different solubility of their cuprous compounds. This process was proposed by Diehl[1], and is carried out by the addition of sulphurous acid and copper sulphate to the solution containing the chloride and sulphocyanate. The cuprous sulphocyanate is then filtered off, leaving the chloride in solution. Diehl determined the chloride volumetrically in the filtrate. We thought it necessary to test the accuracy of this separation. For this purpose portions of potassium or thallium chloride, containing about the same amount of chlorine as the solutions afterwards to be analyzed, were accurately weighed out, and a corresponding quantity of thallium sulphocyanate was added. The salts were then dissolved in hot water, and to the hot solution an excess of sulphurous acid was added, and immediately followed by an excess of copper sulphate solution. The mixture was allowed to stand over night, and the

[1] Chemisches Centralblatt, 1883, 649.

cuprous sulphocyanate was filtered off on a Gooch crucible and washed with sulphurous acid. The filtrate was treated with a considerable quantity of nitric acid, and then the chloride was precipitated by the addition of silver nitrate. The results of these proof analyses are given in the following table:

Salt Taken.	AgCl Obtained.	AgCl Calculated.	Per Cent. Difference.
0.1707 KCl.	0.3289	0.3280	+ 0.27
0.1688 KCl.	0.3233	0.3245	— 0.37
0.5282 TlCl.	0.3172	0.3161	+ 0.35
0.6218 TlCl.	0.3720	0.3722	— 0.05
0.5453 TlCl.	0.3263	0.3263	0.00
0.5525 TlCl.	0.3303	0.3307	— 0.12
0.6099 TlCl.	0.3633	0.3651	— 0.49

The small deviations are partly negative, partly positive. The method, therefore, is shown to be of sufficient accuracy.

4. The Experimental Results.

The experimental data of the solubility experiments are set forth in the following tables. The temperature was 39.75° in all cases.

TlCl in Pure Water.		$TlBrO_3$ in Pure Water.	
Experiment Number.	Weight of AgCl from 100 cc. of Solution.	Experiment Number.	Weight of AgBr from 100 cc. of Solution.
1	0.3617	1	0.4158
2	0.3619 *s*	2	0.4169 *s*
3	0.3605 *s*	3	0.4183 *s*
4	0.3602	4	0.4141
5	0.3631	5	0.4158
6	0.3633 *s*	6	0.4175 *s*
Mean.	0.3618 ± 0.00040[1]	Mean.	0.4164 ± 0.00048
Mol. per liter	0.02523 ± 0.000028	Mol. per liter	0.02216 ± 0.000025

[1] The quantities following the ± signs are not the so-called probable errors, but the average deviations of the mean, as calculated from the expression $\frac{\Sigma\delta}{n\sqrt{n}}$, where $\Sigma\delta$ is the arithmetical sum of the separate deviations and n is the number of measurements.

TlSCN in Pure Water.

Experiment Number.	Weight of AgSCN from 100 cc. of Solution.	Experiment Number.	Weight of AgSCN from 100 cc. of Solution.
1	0.4595	7	0.4639 *s*
2	0.4610 *s*	8	0.4733 *s*[1]
3	0.4579	9	0.4592
4	0.4634 *s*	10	0.4567
5	0.4587 *s*	11	0.4665 *s*
6	0.4560	Mean	0.4603 ± 0.00087
		Mol. per liter	0.02773 ± 0.000053

[1] Omitted in the calculation of the mean.

TlCl and $TlBrO_3$ in Presence of Each Other.

Experiment Number.	Weight of AgCl from 100 cc. of Solution.	Weight of AgBr from 100 cc. of Solution.
1	0.2760[1]	0.2938
2	0.2795 *s*	0.2951 *s*
3	0.2789	0.2935
4	0.2811 *s*	0.2942 *s*
5	0.2794	0.2952
6	0.2802 *s*	0.2951 *s*
Mean	0.2798 ± 0.00030	0.2945 ± 0.00028
Mol. per liter	0.01952 ± 0.000021	0.01567 ± 0.000015

[1] Omitted in the calculation of the mean.

TlSCN and $TlBrO_3$ in Presence of Each Other.

Experiment Number.	Weight of AgSCN from 100 cc. of Solution.	Weight of AgBr from 100 cc. of Solution.
1	0.3672	0.2825
2	0.3666	0.2789
3	0.3680	0.2876 [1]
4	0.3679 *s*	0.2807 *s*
5	0.3665	0.2804
6	0.3657 *s*	0.2799 *s*
7	0.3670 *s*	0.2825 *s*
8	0.3673 *s*	0.2815 *s*
9	0.3663	0.2807
10	0.3668 *s*	0.2834 *s*
11	0.3633 [1]	0.2806
Mean	0.3669 ± 0.00017	0.2811 ± 0.00035
Mol. per liter	0.02210 ± 0.000010	0.01496 ± 0.000018

[1] Omitted in the calculation of the mean.

TlCl and TlSCN in Presence of Each Other.

Experiment Number.	Weight AgCl + AgSCN from 100 cc. of Solution.	Experiment Number.	Weight of AgCl from 100 cc. of Solution.
1	0.6180 *s*	1	0.2593 *s*
2	0.6134 *s*	2	0.2593
3	0.6127 *s*	3	0.2591
4	0.6185	4	0.2590
5	0.6172 *s*	Mean	0.2592 ± 0.00006
6	0.6131	Mol. per liter	0.01807 ± 0.000004
7	0.6150 *s*		Calculated Weight AgSCN from 100 cc. of Solution.
8	0.6158	Mean	0.3568 ± 0.00073
9	0.6200 *s*		
Mean	0.6160 ± 0.00073	Mol. per liter	0.02149 ± 0.000044

In the preceding tables those experiments in which the condition of saturation was reached by cooling a solution saturated at a higher temperature are designated by a small letter *s*. Although these values are, in comparison with the others, as a rule somewhat higher (in general one to four tenths per cent.) with all the salts and pairs of salts, yet in only one case — that of the sulphocyanate in pure water — is the deviation considerable. In this case the difference between the mean values for the supersaturated and undersaturated solutions is a whole per cent. In consequence of the difficulty of preparing saturated solutions of this salt, owing to the tendency of the salt to separate in large crystals on cooling its solution, the general mean has an average deviation of about two tenths per cent.; while in all the other series this quantity does not much exceed one tenth per cent.

In conclusion, the final solubility values and the corresponding diminutions of solubility (which are important in the succeeding calculations) are summarized in the following table:

SUMMARY OF THE SOLUBILITY VALUES.

Solubility.	Of TlCl.	Of TlSCN.
In pure water	0.02523 ± 0.0_428	0.02773 ± 0.0_453
In presence of $TlBrO_3$ . .	0.01952 ± 0.0_421	0.02210 ± 0.0_410
Diminution	0.00571 ± 0.0_435	0.00563 ± 0.0_454

Solubility.	Of TlCl.	Of $TlBrO_3$.
In pure water	0.02523 ± 0.0_428	0.02216 ± 0.0_425
In presence of TlSCN . .	0.01807 ± 0.0_404	0.01496 ± 0.0_418
Diminution	0.00716 ± 0.0_428	0.00720 ± 0.0_431

Solubility.	Of TlSCN.	Of $TlBrO_3$.
In pure water	0.02773 ± 0.0_453	0.02216 ± 0.0_425
In presence of TlCl . . .	0.02149 ± 0.0_444	0.01567 ± 0.0_415
Diminution	0.00624 ± 0.0_469	0.00649 ± 0.0_429

5. Calculation of the Dissociation.

We will now calculate from these numbers the degree of dissociation (a_0) of each of the three salts in its saturated solution in pure water. In this calculation we make use of the four equations which have been given in the first part of this article as the expression of the solubility principles. For the sake of brevity, let

$$m_0 - m = d,$$

and

$$m_0' - m' = d'.$$

When a_0 is eliminated between formulæ (1) and (3), and a_0' between formulæ (2) and (4), there result two equations which may be solved for a with elimination of a'. Through substitution of this expression for a in equation (1) we arrive at the following expression for a_0:

$$a_0 = \frac{1}{m_0}\left[d + \frac{4dd' + d'^2 - d^2}{4d} + \sqrt{dd' + \left(\frac{4dd' + d'^2 - d^2}{4d}\right)^2}\right]$$

We may also obtain a symmetrical expression for a_0'.

Calculation of the dissociation according to these formulæ gives the following results. Each value of the dissociation is accompanied by its precision measure, derived from the average deviations of the corresponding solubility values:

$100a_0$ for TlCl from the TlSCN experiments: 86.5 ± 0.7.
$100a_0$ for TlCl from the $TlBrO_3$ experiments: 86.5 ± 0.4.

$100a_0$ for TlSCN from the TlCl experiments: 86.7 ± 0.4.
$100a_0$ for TlSCN from the $TlBrO_3$ experiments: 86.6 ± 0.4.

$100a_0$ for $TlBrO_3$ from the TlCl experiments: 89.9 ± 0.4.
$100a_0$ for $TlBrO_3$ from the TlSCN experiments: 91.1 ± 0.7.

From these results we get the following as the most probable values of the dissociations:

For TlCl, 86.5 ± 0.3.
For TlSCN, 86.6 ± 0.3.
For $TlBrO_3$, 90.2 ± 0.4.

6. The Validity of the Solubility Principles.

Of much greater interest than the dissociation values themselves is the agreement of the results of the independent experiments of each pair. The agreement is, by chance, exact for the first two pairs, and for the last pair it falls within the limits of experimental error. The conclusion is therefore justified that the solubility principles are exact.

Let us examine more closely the grounds for this conclusion. The validity of the two solubility principles *is assumed* in the calculation of the dissociation values. The calculated values (a_0, a_0', a, and a') are therefore, by definition, those values of the dissociation which must hold if the solubility principles are correct. It cannot, of course, be determined from a single experiment whether these values are the *true* dissociation values; but we have shown that the same values of dissociation which satisfy the solubility principles in one case are, in so far as they are comparable, identical with those which satisfy these conditions in another independent case — a case in which the added salt is chemically different and of different solubility. The results of three such comparisons prove the correctness of the assumptions involved.

The proof can also be presented somewhat differently as follows:

The agreement of the a_0 values calculated for a salt from experiments with it in presence of two others makes the two quantities $m_0{}^2a_0{}^2$ in the two equations corresponding to formula (3) identical. But by formula (3) the identity of the two products $m_0{}^2a_0{}^2$ requires the equality of the two expressions $ma\ [ma + m'a']$ and $m_1a_1\ [m_1a_1 + m''a'']$, thus involving the validity of the second solubility principle. The first principle follows in a similar way, for the agreement of the a_0 values requires the identity of the quantities $m_0\ (1 - a_0)$, and hence the equality of the products $m\ (1 - a)$ and $m_1\ (1 - a_1)$.

With this proof of the validity of the solubility principles with three salts, and up to a total concentration of about 0.04 normal, the original purpose of this investigation was accomplished. There naturally arose, however, a question of perhaps even greater importance, an investigation of which could not be omitted, namely, the question of the trustworthiness of the dissociation values obtained by the electrical conductivity method. The possibility of checking the values of dissociation by means of wholly independent series of

experiments is a peculiarity of the solubility method. For each of the physical methods, as conductivity, freezing point, gives only a single dissociation value, whose correctness can only be estimated by its agreement with the results of other *methods.* Since the dissociations of the three thallium salts have been obtained from two independent agreeing series of experiments by the solubility method, they are almost certainly correct, and the accuracy of values obtained by other methods may be tested by a comparison with these. We have therefore measured the conductivities of the three salts and calculated their dissociations.

7. The Electrical Conductivity of the Salts and the Values of the Dissociation Calculated Therefrom.

In order to obtain comparable values of the dissociation by the electrical conductivity method the molecular conductivity of the three salts has been measured at 39.75°, both in saturated solution and in dilute solutions $\frac{1}{1000}$ and $\frac{1}{1667}$ normal. The limiting value of the molecular conductivity is not, however, reached at the latter dilutions; but on account of the impurities of the water accurate measurements at extreme dilution is attended with great difficulty, and Kohlrausch is the only investigator who has carried out such measurements. However, his experiments show that the increase of the molecular conductivity between a dilution of 1,000 liters, for example, and extreme dilution is in the first place small (about 2 per cent.), and in the second place nearly constant for all binary salts. An extrapolation cannot, therefore, introduce a considerable error.

The complete formula for the calculation of the dissociation is, therefore:

$$a_0 = \frac{m_0 (\lambda m_0 - \lambda \omega)}{K_\nu (\lambda_\nu - \lambda \omega)} = \frac{\mu_{m_0}}{K \mu_\nu} \qquad (5)$$

in which m_0 and a_0 have the same significance as heretofore, ν is the great dilution from which extrapolation is made (1,000 and 1,667 liters), λ_{m_0} and λ_ν are the corresponding specific conductivities in Siemens units, λ_ω is the specific conductivity of the water, μ_{m_0} and μ_ν are the molecular conductivities, and K is the constant by which extrapolation

is made. To determine the value of this constant all the experiments of Kohlrausch[1] with binary salts, ten in number, were examined. Three of these salts were omitted in the calculation of the mean for the following reasons: Potassium acetate because it is an organic salt, and potassium chlorate and lithium chloride because the results are abnormal, in that a maximum value is not reached even at the dilution of 100,000 liters. From the seven remaining series the mean value of K for extrapolation from 1,000 liters is 1.0175; and from 1,667 liters, 1.0125. The average deviation of the first value is 0.0015, and of the second, 0.0010.

The conductivity measurements were carried out according to the method of Kohlrausch in a resistance cell of the form devised by Arrhenius. The solutions, both the saturated and the dilute, were prepared by weighing out the salts and dissolving in the requisite quantity of water. As in the solubility experiments, the molecular concentration of the solutions is referred to that quantity of water which at 39.75° has the volume of one liter. The conductivity of the water used was measured for each solution. At 40° it was 1.7 to 2.4×10^{-10} times that of mercury. In order to check the results as far as possible, the different solutions were each three times freshly prepared, and two portions from each solution were measured with varying resistances.

The three following tables contain the values resulting from these measurements. The numbers show the molecular conductivity of the salts in mercury units at the three concentrations, m_0, $\frac{1}{1000}$, and $\frac{1}{1667}$, at the temperature 39.75°:

Conductivity of TlCl. ($m_0 = 0.02523$.)

	μ_{m_0}	μ_{1000}	μ_{1667}
First solution	157.8	178.9	180.5
Second solution . . .	158.2	179.4	180.5
Third solution . . .	158.2	179.7	.....
Mean	158.1	179.3	180.5
Average deviation . .	0.10	0.18	0.00

[1] Wiedermann's Annalen, **26**, 195.

Conductivity of TlSCN. ($m_0 = 0.02773$.)

	μ_{m_0}	μ_{1000}	μ_{1667}
First solution	145.9	166.9	168.0
Second solution . . .	145.3	167.2	167.3
Third solution . . .	145.3	167.1	.....
Mean	145.5	167.1	167.7
Average deviation . .	0.16	0.06	0.25

Conductivity of $TlBrO_3$. ($m_0 = 0.02216$.)

	μ_{m_0}	μ_{1000}	μ_{1667}
First solution	141.3	155.5	156.3
Second solution . . .	140.6	155.4	156.5
Third solution . . .	140.5	155.4	.....
Mean	140.8	155.4	156.4
Average deviation . .	0.19	0.02	0.07

By extrapolation by means of the constant K two closely agreeing values for μ_∞ were obtained, from the mean of which the dissociation (a_0) of the salts was calculated:

Dissociation of the Salts.

Salt.	μ_∞ from μ_{1000}	μ_∞ from μ_{1667}	μ_∞ : Mean.	Dissociation[1].
TlCl	182.4	182.8	182.6	86.6 ± 0.1
TlSCN . . .	170.0	169.8	169.9	85.6 ± 0.1
$TlBrO_3$ . . .	158.1	158.3	158.2	89.0 ± 0.1

[1] The average deviations of these values are not calculated separately for each salt, on account of the small number of measurements, but are taken as equal for all the salts, and are calculated from the means of the average deviations of all the conductivity measurements on the salts at each dilution.

8. The Agreement of the Dissociation Values Obtained by the Two Methods.

It remains only to compare the dissociation values obtained by means of the solubility measurements with those obtained by the

conductivity method. For this purpose the results of the two methods are placed in parallel columns in the following table:

Salt.	Dissociation from Solubility Effect.	Dissociation from Electrical Conductivity.
TlCl	86.5 ± 0.3	86.6 ± 0.1
TlSCN	86.6 ± 0.3	85.6 ± 0.1
$TlBrO_3$	90.2 ± 0.4	89.0 ± 0.1

The agreement between the values is for the first salt complete, and the difference in the case of the two latter is within the *possible* error of experiment; for though the difference is a little greater than appears probable from an inspection of the average deviations, yet it must be remembered that these are only a measure of the variable error and that they show nothing concerning any constant errors in the method, as, for example, the possibility that the extrapolation constant for thallium salts may be somewhat different from that for the salts investigated by Kohlrausch.

It is therefore proved by our experiments that the *solubility and conductivity methods for the determination of dissociation lead to the same results.* It is, however, important to state explicitly within what limits and under what conditions this proof applies. The preceding statement has been shown to hold true for three salts of very different chemical nature and of somewhat different solubility and dissociation. It seems, therefore, probable that it holds for all binary salts up to the investigated concentration. It is, however, to be remarked that the concentration of our solutions did not exceed 0.03 normal. An extension of the principle to solutions of much greater concentration is, for the present, unwarranted. Finally, it may be stated that the numerical limit to which we have proved the accuracy of our conclusion is about 1 per cent.

9. Conclusion.

The results of this investigation may be summed up as follows: With three salts having solubilities varying from 0.022 to 0.028 normal, it has been proved, first, that the two principles of solubility effect are valid; and, second, that the values of dissociation obtained through the electrical conductivity agree with those calculated from solubilty measurements.

Through this confirmation of the correctness of the values of dissociation obtained by the conductivity method, it is shown conclusively that the law of mass action cannot be applied to determine the change of dissociation with the dilution; for the explanation previously possible, that the disagreement of the observed values with those required by this law is caused by the incorrectness of the dissociation values obtained by the conductivity method, has been shown to be untenable. The law as applied to the dissociation of salts must, therefore, be modified as follows: The product of the concentrations of the ions at different concentrations of the solution is *not* in a constant ratio to the concentration of the undissociated salt. But, corresponding to any given concentration of undissociated salt, the product of the concentrations of the ions has a constant value, which is altogether independent of the relative concentrations of the separate ions.

Finally, it may be remarked that further solubility experiments of a similar nature would be of interest to decide the question up to what concentration the solubility principles and the dissociation values obtained by the conductivity method are trustworthy. Since the dissociation values have been already obtained for three salts by our experiments, such an investigation is rendered much less arduous.

FURTHER EXPERIMENTS FOR DETERMINING THE FUSIBILITY OF FIRE-CLAYS.[1]

By H. O. HOFMAN.

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A PREVIOUS paper[2] has described the experiments made by Mr. C. D. Demond and the present writer to ascertain by an indirect method the refractory values of clays. Fire-clays were mixed with varying proportions of calcium carbonate and calcium carbonate and silica to render them fusible at temperatures below the melting point of platinum and common brick-clays, with alumina and silica to decrease their fusibility; the object being to arrive at a standard temperature at which fire-clays as well as common brick-clays could be tested; the amount of ingredient required by each clay for fusion being the measure of its refractoriness. The behavior of the samples in the fire gave such a satisfactory series, both in the descending scale with fire-clay and the ascending scale with common brick-clay, that it seemed an easy matter to assume a standard temperature 1500° C., and to add fluxing or refractory substances to the clays until they melted at this temperature. This was found, however, to be very difficult. Samples of Mount Savage clay, with from 40 to 65 per cent. of calcium carbonate and mixtures of calcium carbonate and silica, showed very plainly the effect of the successive additions; but there was only a gradual transition, instead of the complete change which had been anticipated, the most refractory cone remaining erect, or nearly so, the next bending slightly, and so on by degrees, until in the last of the series the apex touched the base. It is possible to arrive at somewhat satisfactory results by assuming the behavior of a certain cone within a given time as a standard and working out from this; but such a method be-

[1] Read at the Florida Meeting of the American Institute of Mining Engineers.
[2] Technology Quarterly, 6. 301.

comes necessarily individual and can scarcely be made applicable for general use.

Seger's Direct Method.

The direct method of testing is to place a sample of clay, with accepted standards for comparison, in a crucible, and expose them in a suitable furnace to different temperatures until the sample shows the same degree of fusion as one of the standards. The seven clays of Bischof,[1] which formed the standards for a number of years, not being any longer obtainable (the character of the deposits having changed), Seger prepared graded mixtures of potash, lime, alumina, and silica to take the place of the Bischof clays.

The following is a description of the experiments carried out in the metallurgical laboratory of the Massachusetts Institute of Technology with some of the leading fire-clays of this country according to Seger's method.[2] Acknowledgments are due to Mr. G. H. Anderson, S.B., and to Mr. R. Loring, S.B., for their careful and patient work, which made it possible to carry to a successful end the large number of experiments necessary. The apparatus, etc., was all imported from the *Chemisches Laboratorium für Thonindustrie*, at Berlin, to insure accuracy in the work.

1. *The Furnace.* — The furnace used was the Deville furnace, represented in Figures 1, 2, and 3. This is a small cylindrical furnace, *a*, of $\frac{1}{8}$ inch sheet iron, lined with refractory material. It is open at the top and closed near the bottom by a cast-iron plate, *b*, having a large central opening surrounded by three rows of small perforations. Below this is the air chamber, *c*, with blast inlet pipe, *d*. The furnace rests upon the iron plate, *e*, which has an upturned edge and three legs, which are riveted to it. The place where furnace and plate meet is luted with a sandy, non-shrinking clay. The furnace is lined for the first $5\frac{8}{8}$ inches with Spaeter's sintered magnesite from Veitsch, Styria, the rest of the lining being a mixture of 90 per cent. magnesite and 10 per cent. Zettlitz kaolin. The composition of the two refractories is shown by the following analyses.

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[1] Technology Quarterly, 6, 304, 305.

[2] Thonindustrie-Zeitung, 1893, 1281.

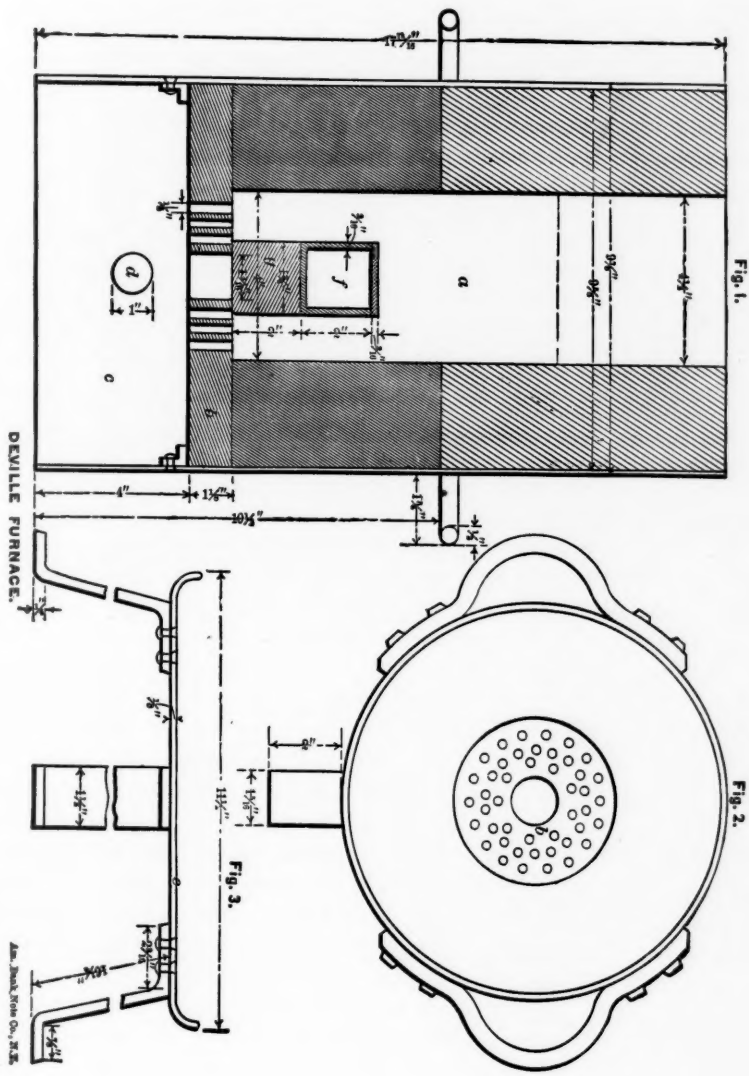

DEVILLE FURNACE.
Fig. 1.
Fig. 2.
Fig. 3.

TABLE I.

ANALYSES OF REFRACTORY MATERIALS.

	Al_2O_3.	SiO_2.	MgO.	CaO.	K_2O.	Fe_2O_3.	Chemist.
Sintered magnesite[1] . .	0.86	2.35	88.22	0.87	....	7.07	Winkler.
Zettlitz kaolin[2].	38.54	45.68	0.38	0.08	0.66	0.90	Bischof.

After carrying out about sixty fusions the lower part of the lining began to be affected. This was probably caused by the ash of the charcoal and gas carbon. The slag spread somewhat over the small perforations in the grate and had to be pried off. Some of the unaltered lining adhered to the slag and broke off, thus enlarging the cylinder and making it require more fuel. The furnace lining cannot well be patched, and so it must be renewed. For this purpose the lining is broken out, crushed to pass a 4-mesh sieve (the scorified part being also used), moistened with from 8 to 10 per cent. of hot water, covered and kept in a sheltered place for from two to three days that the water may be thoroughly absorbed. The hydration of magnesia causes the mass to harden slightly, when it is crushed again, if necessary, and moistened with sufficient water to make it cohere into a lump when squeezed in the hand, but not to wet the hand. The core around which the lining is to be tamped is a wooden truncated cone, $17\frac{3}{4}$ inches high and $3\frac{1}{2}$ and 4 inches in diameter, having a spindle $1\frac{1}{8}$ inches in diameter at the smaller end, which fits into the central opening of the cast-iron grate. It is enveloped in five layers of newspaper, the last one being fastened with mucilage to prevent its unrolling. When the core is in place the lining is filled in in layers about 2 inches thick, rammed down with a stick, say $\frac{3}{4}$ inch in diameter, new magnesite, prepared in the same way as the old, being used against the core, old magnesite against the iron shell for a depth of 6 inches, after which the old is exclusively used, the top layer being tamped so as to rise toward the core and pounded down firmly with an iron mallet or hammer. The furnace is now laid on its side, and the core, loosened by gently tapping the spindle, is drawn out. Most of the paper will adhere to the lining, to be burnt out later on. It is necessary to remove the core as soon as the tamping is finished, as it is liable to

[1] Circular of the Pittsburg Testing Laboratory.

[2] Technology Quarterly, 6, 304.

swell, thus causing difficulty in getting it out and loosening the lining. Should this happen, it is best to take it all out and reline the furnace at once, instead of having to do it a little later. The furnace is now placed on two bricks and air-dried for from five to six days, and the remaining moisture is finally driven off by keeping a wood fire going in it for two days, no firing being necessary during the intervening night.

In experimenting with the furnace, one improvement in the construction suggested itself. After an experiment the gas carbon surrounding the support and part of the crucible is discharged through the central opening in the grate into the air chamber, to clear which the furnace has to be lifted, which necessitates fresh luting. This might be avoided by having an opening with collar in the supporting plate, to be closed by a hinged door and fastened with a tightening screw, an asbestos packing in the mortise of the door serving to make the joint air-tight.

The top of the furnace is uncovered. To draw off the gases, ashes, and particles of finely divided fuel into the flue, a piece of sheet iron with peephole was suspended in an inclined position over the furnace. In this way it was an easy matter to watch the surface of the charge, remove the crucible as soon as it became visible, and clean the furnace when an experiment was completed.

2. *The Crucible and its Support.* — The crucible, *f*, in which the clay and standard cones are placed to be brought to the intense heat necessary for fusion, consists of equal parts of calcined alumina and Zettlitz kaolin mixed with sufficient raw kaolin to permit the whole to be properly moulded. It is so infusible that the most refractory clay, the Rakonitz clay-slate of Saarau, Silesia, can be melted down in it without its being appreciably injured by the high temperature. The lid is of the same material as the crucible. The crucible formerly used,[1] consisting of a mixture of calcined magnesite and chromite moistened with magnesium chloride and poured with alumina, has been given up, since the lining, as well as the chromic oxide, somewhat affected the samples that were being tested.

The crucible support, *g*, is made of refractory material, which begins to show signs of fusion only at a temperature represented by Seger cone No. 35. It used to be made with a small cylindrical projection

[1] Thonindustrie-Zeitung, 1892, 676; 1893, 1281.

at the bottom, which fitted into the central opening of the grate, *b*, and thus insured its being directly in the middle. This was very convenient when starting work in a cold furnace where the grate is invisible.

3. *Seger Cones and Mould.* — The composition of the artificial refractory mixtures prepared by the late Professor Seger to take the place of the standard fire-clays of Dr. Bischof is shown in Table II:

TABLE II.

SEGER CONES COMPARED WITH BISCHOF'S STANDARD CLAYS.

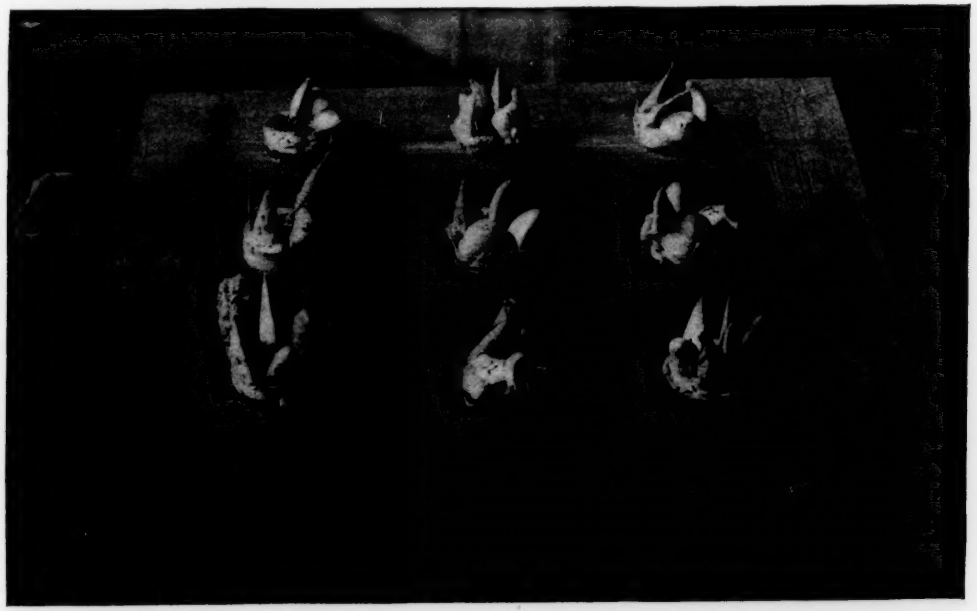
SEGER CONES.[1]					BISCHOF STANDARD CLAYS.[2]	
Number.	Composition.				Corresponding No.	Locality.
	K_2O.	CaO.	Al_2O_3.	SiO_2.		
26	0.3	0.7	7.2	72	VII	Niederpleis, Nassau.
27	0.3	0.7	20	200	....	.....
28	....	....	1	10	VI	Cassel, Hesse.
29	....	....	1	8	....	.....
30	....	....	1	6	V	Grünstadt, Palatinate.
31	....	....	1	5	....	.....
32	....	....	1	4	IV	Coblentz, Rhenish Prussia.
33	....	....	1	3	III	Andennes, Belgium.
34	....	....	1	2.5	....	.....
35	....	....	1	2	II	Zettlitz, Bohemia.
36	Rakonitz clay-slate.				I	Saarau, Silesia.

There are twelve standard mixtures, while Bischof only had seven standard clays. They are formed into small three-sided pyramids $\frac{1}{8}$ inch at the base and $\frac{11}{12}$ inch high, having their respective numbers, Nos. 26 to 36, impressed on them. Their behavior in the fire is shown in Figure 4, representing tests with clays, fire-bricks, and fire-sands, made at Berlin and sent to the writer by Mr. Cramer to serve as a guide at the beginning of the present work. Figure 5, with

[1] Seger, Thonindustrie-Zeitung, 1888, 163. Seger-Cramer, Thonindustrie-Zeitung, 1893, 1252.

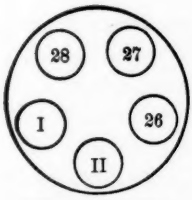
[2] For analyses see Technology Quarterly, 6, 304.

FIG. 4.



Tests of Fire-clays, Fire-bricks, and Fire-sand.

Fig. 5.

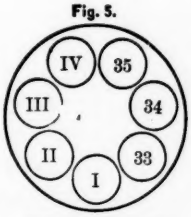


SEGER CONES.

26 GLOBULAR.
27 SHORTENED.
28 WELL-BEADED.

CLAY SAMPLES.

I. COMPLETELY FUSED AND ABSORBED BY BOTTOM LINING, MUCH BELOW CONE 26.
II. EQUAL TO CONE 27.

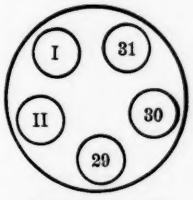


SEGER CONES.

33 GLOBULAR.
34 SHORTENED.
35 UNCHANGED.

FIRE-SAND SAMPLES

I. EQUAL TO CONE 33.
II., III. AND IV. STAND BETWEEN CONES 34 AND 35.

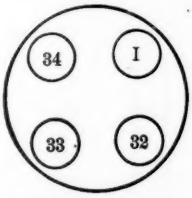


SEGER CONES.

29 GLOBULAR.
30 SHORTENED.
31 SLIGHTLY BEADED.

FIRE-CLAY SAMPLES

I. EQUAL TO CONE 30.
II. EQUAL TO CONE 30.

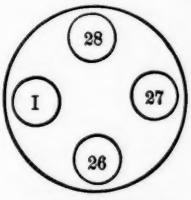


SEGER CONES.

32 GLOBULAR.
33 SHORTENED.
34 SLIGHTLY BEADED.

FIRE-BRICK SAMPLE

I. EQUAL TO CONE 33.

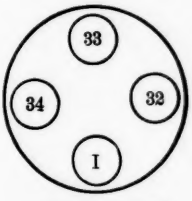


SEGER CONES.

26 GLOBULAR.
27 SHORTENED.
28 WELL-BEADED.

FIRE-CLAY SAMPLE

I. EQUAL TO CONE 28.

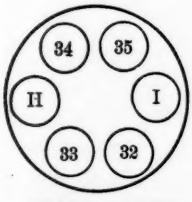


SEGER CONES.

32 LENTICULAR.
33 GLOBULAR.
34 SLIGHTLY BEADED.

FIRE-CLAY SAMPLE

I. EQUAL TO CONE 33.

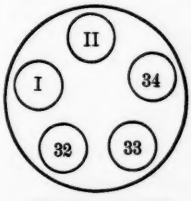


SEGER CONES.

32 SHORTENED.
33 SLIGHTLY BEADED.
34 FRITTED.
35 UNCHANGED.

FIRE-BRICK SAMPLES

I. EQUAL TO CONE 32.
II. STANDS BETWEEN CONES 32 AND 33.

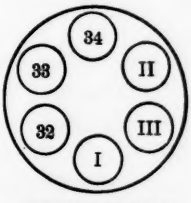


SEGER CONES.

32 LENTICULAR.
33 SHORTENED.
34 BEADED.

FIRE-SAND SAMPLES

I. STANDS BETWEEN CONES 33 AND 34.
II. EQUAL TO CONE 34 OR STANDS SLIGHTLY LOWER.



SEGER CONES.

32 SHORTENED.
33 SLIGHTLY BEADED,
34 UNCHANGED.

FIRE-CLAY SAMPLES

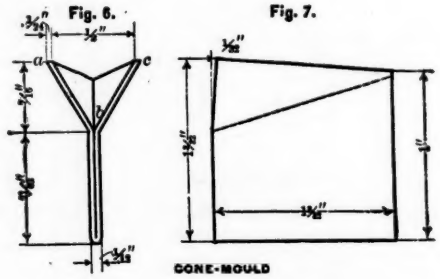
I. AND II. STAND BETWEEN CONES 32 AND 33.
III. EQUAL TO CONE 33.

DIAGRAMS OF TESTS, SHOWING BEHAVIOR OF CONES AND SAMPLES.

legend, describes their behavior in detail, the different changes during fusion being indicated by the terms "beaded" (the apex only showing signs of fusion), "shortened" (the pyramid bending or sinking and bulging toward the base), "globular" (the pyramid becoming round or oval), and "lenticular" (more or less complete fusion, the sample being sometimes slightly raised in the middle, sometimes slightly depressed, sometimes completely absorbed by the porous bottom lining of the crucible).

The writer cannot agree with Bischof's[1] adverse criticism of these cones. After having melted down close upon two hundred Seger cones in seventy separate experiments, he has still to find one instance where the cones did not fuse in the order indicated by their numbers.

The mould and scraper used in making pyramids from the sample to be tested are shown in Figures 6, 7, 8, and 9. The mould, Figures

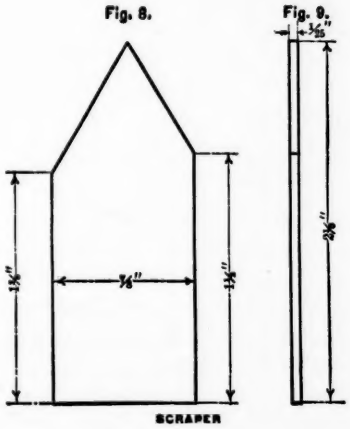


6 and 7, consists of a small oblong piece of sheet brass folded crosswise, with two of the corners turned outward just far enough to form an inclined trough and soldered in the middle, the solder being filed smooth. The scraper, Figures 8 and 9, is a piece of sheet zinc pointed at one end to fit accurately into the triangle *a b c*.

The dimensions here shown should be slightly reduced if the test-cone is to correspond exactly to the size of the Seger cone. The mould, Figures 5, 6, and 7, produces a three-sided pyramid, 0.5 inch at the base and 1 inch high, while the corresponding measurements of the Seger cone are $\frac{1}{8}$ inch and $\frac{11}{12}$ inch. The difference of size seems to make no perceptible difference in result; but not more than three of the larger cones can be put into the crucible at once, which is a decided disadvantage.

[1] Thonindustrie-Zeitung, 1893, 1337; 1894, 89. See also Aaron's rejoinder, Thonindustrie-Zeitung, 1893, 1337; 1894, 90.

4. *Method of Working.* — In preparing refractory material for a test, it is slightly calcined (if it contains any organic matter), and, when cool, moistened on a glass plate with water containing 5 per cent. of dextrine, and worked with a spatula to a stiff paste, plastic fine-grained clay requiring less water than sandy and open-grained. The paste is now pressed with a spatula into the mould, which is placed over the scraper. This is slowly pushed upward and thus releases the sample pyramid. It is well to slightly oil the upper part of the mould to prevent the clay from adhering and the top of the pyramid from bending over. The sample is now air-dried over night,



and then slowly heated on an iron plate to drive off the rest of the moisture. Usually two dried samples are placed with three Seger cones in a crucible. To hold the cones in position refractory clay is first introduced to a depth of say $\frac{3}{8}$ inch and then pressed down with a round stick, say $1\frac{1}{8}$ inches in diameter and 4 inches long. With samples melting below Seger cone No. 34, the bed consists of clay melting at a temperature indicated by Seger cone No. 35; with samples more refractory than Seger cone No. 34, the bed consists of equal parts of kaolin and alumina. In making the clay bed, one half is pressed down firmly before the rest is added. This is then tamped in gently, leaving it softer than the bottom, so that when the cones are introduced the latter will be undisturbed and the whole firm. In

putting the pyramids in position a pair of straight steel pinchers was used, one arm of which had been flattened out and then bent into a trough shape.

The fuel best suited for the furnace is gas carbon, as it is hard, dense, and contains less than 0.1 per cent. of ash. It was crushed in a Gates laboratory crusher to pass a 2-mesh sieve, and then screened on a 4-mesh sieve to remove the fines. In order to ignite the carbon about 200 grams of charcoal are required. This was put through the same crusher, everything passing through a 2-mesh sieve being rejected. The fire is started with about 30 grams of newspaper.

A pair of cupel tongs, with points bent at right angles to the arms and slightly curved to fit the cylindrical form of support, crucible, and lid, were found convenient. When the crucible is in position, the blast is slowly started and the paper ignited and pressed down into the furnace with the tongs, to be followed by charcoal and gas carbon. The pressure of the blast is gradually increased, and when nearly all the carbon has been consumed and the crucible becomes visible (a blue glass being necessary to permit the watching) the blast is shut off and the crucible removed, the support usually adhering to it. The different temperatures are obtained by varying the amount of gas carbon and the blast. In the Berlin laboratory, foot bellows, 20 inches in diameter, are used; at first they are trodden twenty-five times a minute, the number of treadings being afterwards increased to fifty, and a test lasting about one hour. The use of foot bellows being rather awkward and time-consuming, a small Sturtevant fan furnished the blast in the writer's experiments, the connection between the blower and the rubber hose attached to the blast pipe of the furnace being made with a tuyère bag. Into the rubber hose was inserted a glass tube, and this connected by rubber tubing with a U-shape water gauge; the pressure of the blast was regulated by tightening or loosening a clamp inclosing the tuyère bag.

The first step in experimenting with the furnace was to find out the amount of gas carbon and the pressure required for the different Seger cones. Table III gives the leading results obtained. It took about six minutes to feed in the charge, fresh charcoal or gas carbon being given when the glow had penetrated the preceding charge of fuel. The pressure of the blast was slowly increased. Starting with just enough air to permit of introducing the ignited paper without its blazing up too violently, it was raised to $\frac{1}{2}$ inch when the first scoopful

TABLE III. — FURNACE TESTS OF SEGER CONES.

Seger Cone.			Fuel Charge.				Blast Pressure.								Furnace.			
							Inches water, at minutes after starting.									Appearance of, in minutes after starting.		
No.	Form after fusion.	Luster after fusion.	Paper. (Grams.)	Charcoal. (Grams.)	Gas carbon. (Grams.)	Time of feeding. (Minutes.)	Inch.	Min.	Inch.	Min.	Inch.	Min.	Inch.	Min.	Initial condition.	First CO-flame.	Steady CO-flame.	Crucible.
26	Beaded	Dull	30	200	900	6	0.5	1	1	3	.....	.....	.....	.....	Cold.	8	10	37
26	Globular	Dull, vitreous	30	200	925	7	0.5	1	1	7	.....	.....	.....	.....	Cold.	13	18	35
26	Lenticular	Vitreous	30	200	950	7	0.5	1	1	7	.....	.....	.....	.....	Cold.	13	18	38
27	Globular	Dull	30	200	925	7	0.5	1	1	7	.....	.....	.....	.....	Cold.	13	18	35
27	Globular	Dull, vitreous	30	200	950	7	0.5	1	1	7	.....	.....	.....	.....	Cold.	13	18	38
27	Lenticular	Vitreous	30	200	995	7.5	0.5	1	1	6	1.5	17	.....	.....	Cold.	19	23	41
28	Shortened	Dull	30	200	925	7	0.5	1	1	7	.....	.....	.....	.....	Cold.	13	18	35
28	Lenticular	Dull	30	200	950	7	0.5	1	1	7	.....	.....	.....	.....	Hot.	13	18	38
28	Lenticular	Vitreous	30	200	925	6	0.5	3	1	6	1.5	12	.....	.....	Hot.	12	13	35
29	Globular	Dull	30	200	900	6	0.5	1	1	3	1.5	6	.....	.....	Hot.	11	12	29
29	Lenticular	Vitreous, dull	30	200	925	6	0.5	1	1	3	1.5	6	.....	.....	Hot.	12	13	35
29	Lenticular	Vitreous	30	200	1,000	6	0.5	1	1	3	1.5	5	.....	.....	Hot.	15	17	45
30	Shortened	Dull	30	200	900	6	0.5	1	1	3	1.5	6	.....	.....	Hot.	11	12	29
30	Lenticular	Dull, vitreous	30	200	925	6	0.5	1	1	3	1.5	6	.....	.....	Cold.	11	14	28
31	Globular	Dull	30	200	925	6	0.5	1	1	3	1.5	6	.....	.....	Hot.	12	13	31
31	Lenticular	Vitreous	30	200	925	6	0.5	1	1	3	1.5	6	.....	.....	Cold.	10	11	29
32	Shortened	Dull	30	200	925	6	0.5	1	1	3	1.5	6	.....	.....	Cold.	11	14	28
32	Globular	Dull	30	200	1,025	6	0.5	1	1	3	1.5	6	.....	.....	Cold.	11	13	31
32	Lenticular	Dull	30	200	950	6	.....	.....	1	1	1.5	6	2	17	Hot.	10	12	30
33	Shortened	Dull	30	200	1,025	6	.....	.....	1	1	1.5	6	.....	.....	Hot.	11	15	36
33	Lenticular	Dull	30	200	1,050	6	0.5	1	1	3	1.5	6	.....	.....	Hot.	12	13	35
33	Globular	Dull	30	200	925	6	0.5	1	1	3	1.5	6	2	17	Cold.	10	14	24
34	Beaded	Dull	30	200	925	6	0.5	1	1	3	1.5	6	.....	.....	Hot.	10	11	25
34	Globular	Dull	30	200	925	6	.....	.....	1	1	1.5	6	2	17	Hot.	9	11	29
34	Lenticular	Dull	30	200	975	6	.....	.....	1	1	1.5	6	2	17	Hot.	10	11	?
35	Beaded	Dull	30	200	925	6	.....	.....	1	1	1.5	6	2	17	Cold.	?	17	26
35	Globular	Dull	30	200	925	6	.....	.....	1	1	1.5	6	2	17	Hot.	9	11	29
35	Lenticular	Dull	30	200	1,000	6	0.5	1	1	3	1.5	6	2	17	Hot.	8	10	25

TABLE IV.—Analyses and Tests of Standard American Fire-Clays.

Number.	Fire-Clay, from.	Sampled by.	Analyzed by.	Al_2O_3. (Per cent.)	SiO_2, combined. (Per cent.)	H_2O, combined. (Per cent.)	Total clay material. (Per cent.)	SiO_2, non-combined. (Per cent.)	TiO_2. (Per cent.)	Total sandy material. (Per cent.)	MgO. (Per cent.)	CaO. (Per cent.)	K_2O. (Per cent.)	Na_2O. (Per cent.)	Li_2O. (Per cent.)	Fe_2O_3. (Per cent.)	Total fluxing material. (Per cent.)	H_2O, hygroscopic. (Per cent.)	Organic matter. (Per cent.)	Loss on ignition. (Per cent.)	Sum total.	Corresponding Seger cone. No.
1	Athens, Texas	Ladd.	Ladd.	20.71	31.82	7.17	59.70	37.	06	37.06	0.39	0.22	0.69	0.39	.....	1.01	2.70	1.82	....	8.99	99.46	29
2	Blandford, Mass. (Kaolin.)	Twichell.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29
3	Mt. Savage, Md. (Soft.)	Ladd.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29–30
4	Woodbridge, N. J. (Dixon.)	Ladd.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30–31
5	Parall, Ohio. (No. 4.)	Ladd.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30–31
6	St. Louis, Mo. (Christie, raw clay.)	Ladd.	Ladd.	21.16	26.03	8.94	56.13	38.	32	38.32	0.30	0.61	0.86	0.88	.....	2.72	5.37	2.62	....	11.57	99.82	31–30
7	Carbondale, Col. (Kaolin.)	Ladd.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	31
8	Pueblo,[1] Col. (20 miles S. W. of.)	Gilbert.	Steiger.	24.72	28.76[2]	8.63[2]	62.11	34.76[2]	0.68	35.44	0.13	0.30	trace	trace	P_2O_5 trace	0.43	0.86	1.36	0.40	10.39	100.17	31
9	Golden, Col.	Ladd.	Ladd.	31.72	45.99	13.30	91.01	5.	22	5.22	0.23	0.36	0.48	0.45	.....	0.75	2.27	0.83	....	14.13	98.50	32–31
10	Parall, Ohio. (No. 5.)	Ladd.	Ladd.	28.14	32.03	10.22	70.39	26.	81	26.81	0.28	0.49	0.15	0.46	.....	1.67	3.05	1.23	....	11.45	100.25	32
11	Woodbridge,[1] N. J. (Quartz-kaolin.)	Smock.	?	17.46	16.50	6.30	40.26	57.10	0.90	58.00	....	.....	0.12	0.21	.....	0.54	0.87	0.50	....	6.80	99.63	32–33
12	St. Louis, Mo. (Evans and Howard.)	Ladd.	Ladd.	23.26	27.56	10.20	61.02	31.	82	31.82	0.42	0.65	0.54	0.79	.....	3.24	5.64	2.74	....	12 94	98.48	32–33
13	Mineral Point,[1] Ohio	Orton, Sr.	Lord.	31.84	35.39	11.68	78.91	17.13	1.68	18.81	0.19	0.50	0.59	.. ...	.....	0.67	1.95	0.69	....	12.37	100 36	33
14	Carbondale, Col.	Ladd.	Ladd.	31.75	36.03	12.76	80.54	17.	00	17.00	0.04	0.87	0.16	0.45	.....	1.06	2.58	2.42	....	15.18	100.12	33–34
15	Sciotoville, Ohio.	Ladd.	Ladd.	40.04	43.28	13.11	96.43	0.	31	0.31	0.17	0.15	0.30	0.38	.....	2.40	3.40	1.40	....	14.51	100.14	34
16	Sand Hills,[1] N. J. (Woodbridge.)	Smock.	?	35.94	36.20	12.10	84.24	12.20	1.50	13.70	....	.....	0.08	.....	.....	0.96	1.04	1.10	....	13.20	100.08	34
17	Woodland, Pa.	Ladd.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34–35
18	Mt. Savage, Md. (Hard.)	Ladd.	Ladd.	38.14	41.93	12.62	92.69	5.	90	5.90	0.17	trace	0.49	0.42	.....	1.31	2.39	1.18	....	13.80	100 98	34–35
19	High Hill, Md.	Ladd.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34–35
20	Woodbridge, N. J.	Ladd.	Ladd.	36.85	43.46	14.03	94.34	1.	92	1.92	0.83	0.15	0.21	0.28	.....	0.99	2.46	1.34	....	15.37	98.72	35–34
21	Sayreville,[1] N. J.	Smock.	?	38.66	41.10	13.55	93.31	3.10	1.20	4.30	....	.....	0.28	0.18	.....	0.74	1.20	1.00	....	14.55	99.81	35
22	Portsmouth, Ohio.	Orton, Jr.	Orton, Jr.	39.93	45.05	14.15	99.13	with clay.	....	.....	0.18	0.07	0.21	trace	.....	0.47	0.93	....	....	.....	100.06	35
23	Sciotoville, Ohio	Orton, Sr.	Mariner.	34.78	52.00	10.96	97.74	with clay.	....	.....	....	.....	0.78	.....	.....	1.48	2.26	....	....	.....	100.00	35
24	Burt's Creek,[1] N. J. (So. Amboy.)	Smock.	?	38.34	42.90	13.50	94.74	1.50	1.20	2.70	....	.....	0.26	0.18	.....	0.86	1.30	1.10	....	14.60	99.84	35
25	Woodbridge, N. J. (Spa Spring.)	Smock.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	36–35

[1] The hygroscopic water is included in the sum total.

[2] Calculated. Analysis of clay No. 8 was made in the laboratory of the United States Geological Survey. Analyses of clays Nos. 11, 16, 21 and 24 are copied from the *Report on Clays* of the Geological Survey (Trenton, 1878, Nos. 22, 14, 20, and 19, p. 297), as the clays there represented, according to Prof. J. C. Smock, are of the same composition as those tested. Analyses Nos. 13 and 23 are taken, at the suggestion of Prof. Edward Orton, Sr, from Vol. V of the Geological Survey of Ohio (Columbus, 1884, p. 648); the corresponding numbers in the table are Nos. 1 and 6.

of charcoal had been given, to 1 inch when all the charcoal and some gas carbon had been fed, and then gradually to the required pressure, the highest being 2 inches. When the pressure required for a certain experiment had been reached, it was maintained at that point until the end by increasing the amount of air in proportion to the burning away of the carbon. The result of this is that toward the end of an experiment the gas carbon is burnt quickly, and thereby the temperature greatly raised. This is important if the samples are to undergo the desired change. The table shows the different effects obtained with different weights of gas carbon and varying pressures of blast. Of course it must be borne in mind that the figures depend upon the character of the gas carbon and the condition of the furnace, and should therefore vary when these differ from those used. It has been previously said that, after making some sixty experiments, the lining of the furnace showed signs of becoming vitrified, which slightly enlarged the diameter of the hottest zone, with the result that more fuel or a higher pressure of blast, or both, were required. In making this kind of experiment the first thing is to standardize the furnace, if the expression be allowable, by following in a general way the data given in the table and then keeping a tabular record of all the experiments made afterward, the latest successful experiments serving as guides for future work. In the table the condition of the furnace when the experiment was made is given as cold or hot; the former means that no work had been done with the furnace on the day of the experiment, the latter that one or two experiments had preceded the one in question.

5. *Results with American Fire-Clays.* — In Table IV are recorded the results obtained in testing standard American fire-clays by Seger's method. Of the twenty-five samples, fifteen were received from Dr. G. E. Ladd, a geologist who, having made the study of clays a specialty, devoted much time and money in visiting the principal deposits and collecting samples (weighing each about fifty pounds) for investigations of his own. These samples are specially good, being taken in a systematic way by a disinterested expert. The results of the fire-tests show, therefore, the true character of the beds in 1893. How this may differ from samples taken at an earlier date is seen by comparing tests Nos. 15 and 23, both representing Sciotoville clay; No. 23 the clay of 1884, and No. 15 that of 1893. Only eight of Dr. Ladd's samples have so far been analyzed; the analyses of the other seven

will appear later. Professor J. C. Smock kindly furnished the writer with abundant material from the representative clay beds of New Jersey. The analyses quoted are not actually those of the clays that were tested, but are sufficiently close to permit their being used. Of the three Ohio clays received from Professors Edward Orton, Sr., and Edward Orton, Jr., only the sample from Portsmouth is represented by the actual analysis. The clay from Pueblo, Colorado, received from Mr. G. K. Gilbert, of the United States Geological Survey, is represented by the true analysis. The last column of Table IV shows the comparative fire-resisting values of the clays. They range from Seger cone No. 29 to No. 35, and above; a pyramid of Spa Spring washed clay from Woodbridge, New Jersey, melting down only to the size of a pea, when Seger cone No. 35 had been completely melted.

In addition to these tests of standard clays, five samples of low-grade fire-clays from Ohio and Pennsylvania, kindly furnished by Professor Edward Orton, Jr., have been similarly tested. Table V gives the analyses and results:

TABLE V. — ANALYSES[1] AND TESTS OF LOW-GRADE FIRE-CLAYS.

Number.	Fire-clay sampled and analyzed by Prof. Edward Orton, Jr., from.	Al_2O_3. (Per cent.)	SiO_2 total. (Per cent.)	H_2O combined. (Per cent.)	Total clay material. (Per cent.)	MgO. (Per cent.)	CaO. (Per cent.)	K_2O. (Per cent.)	Na_2O. (Per cent.)	Fe_2O_3. (Per cent.)	Total fluxing material. (Per cent.)	H_2O, hygroscopic. (Per cent.)	Loss on ignition. (Per cent.)	Sum total. (Per cent.)	Corresponding Seger cone. No.
1	Zanesville, Ohio . .	22.95	64.26	6.74	93.95	0.37	0.45	1.81	0.15	1.28	4.06	2.05	8.79	100.06	26
2	Salineville, Ohio . .	26.60	56.44	7.57	90.61	0.63	0.47	3.20	0.26	2.00	6.56	2.48	10.05	99.65	27–26
3	New Brighton, Pa. .	24.88	63.55	6.96	95.39	0.47	0.56	2.27	....	1.17	4.47	1.38	8.34	101.24	28
4	Zanesville, Ohio . .	21.13	66.21	6.29	93.63	0.18	0.51	1.42	0.38	1.28	3.77	1.65	7.94	99.05	29–28
5	East Palestine, Ohio.	25.12	59.54	7.75	92.41	0.51	0.57	1.95	....	1.57	4.60	2.63	10.83	99.64	29–28

It will be seen that the clays of Table V correspond approximately in refractory quality to Seger cones Nos. 26, 27, and 28 (although No. 27 is not accurately represented), thus completing, with Table IV, the range covered by the Bischof standards, as shown in Table II.

[1] The hygroscopic water is included in the sum total.

A DISCUSSION OF STATE LEGISLATION ON HIGHWAYS IN THE UNITED STATES.

By ROY STONE.

Received April 11, 1895.

We have long heard of abandoned farms, and we are beginning to hear of factories abandoned through the process of natural selection and the "survival of the fittest," but in one of my recent journeys to the West I discovered a more startling object — an abandoned railroad, with rusting rails, rotting bridges, weed-grown roadbed, and even the right of way lapsing through non-user.

This road led from a large and prosperous town through a rich farming district; it connected with other railroads at both ends and had no rival line, yet it had not business enough to pay operating expenses even as a feeder to its connections; and I find upon inquiry that this is only one of several roads thus situated.

Here is an object lesson too plain to be misunderstood. We have overdone railroad building in this country as a means of development, and must search for other methods of bringing the country up, even to the point of making its present railways profitable. In its bearing on the question of employment for engineers that lesson has doubtless come home to many instructors in engineering, and even their pupils must be casting anxious eyes into the future to see what employment is to replace railway building and give suitable occupation to the ceaseless stream of graduates in the art of construction. And were it not that to those who are properly equipped human progress opens constantly new fields for human effort, there might be room for serious apprehension in the sudden extinction of so large a share of the world's demand for constructive skill.

Among the growing fields for the employment of civil engineers may be reckoned ship canals, water powers, irrigation, and highways, and of all these the last gives much the most hope of filling the place of railroads.

Many institutions are therefore awaking to the need of instruction in this branch of engineering. There is need, however, in this country and in this field for something more than mere technical instruction. Under a paternal government the engineer needs only to know how to build roads; the authorities will do the rest. Under a popular government he must know how to get them built. His duty as a citizen and his professional interest alike require that he should know all about the laws and ways and means, and all the facts and arguments bearing on the question, and be as well able to promote road improvements as to execute them.

Professor Swain is, therefore, wise in proposing that one of my lectures shall "cover an account of what has been done in the United States in the past few years in improving the condition of the roads."

But before entering upon the question of what has been done by the various States I will speak of what has been done by the general government. It is not generally known that the government was engaged in building common roads for seventeen years before it began the improvement of rivers and harbors, and that the construction of roads has been kept up to a greater or less extent ever since.

Every one has heard of the magnificent Cumberland road which crossed the Alleghany Mountains and led to the Mississippi, but few are aware that while this road was in progress twelve national roads were laid out in the States and Territories, making what was regarded then as a complete system of highways, and that more or less work was done in opening and constructing these various highways.

The monetary crisis of 1836 put an end to all great schemes of government expenditure, and from that time to this only a few military roads have been made, and of late years only those leading to national cemeteries.

The constitutional question as to the power of the government to build roads, while it has been frequently raised, has never seriously interfered with actual road construction, and the general opinion is that there would be nothing in the way of an extended use of national aid to road building, at least as regards military and post roads. The necessity for military roads has been insisted upon by many army officers, in view of the difficulty of moving troops by rail for the suppression of domestic disorder at a time when railway employees are in sympathy with the malcontents, as has frequently happened of late years.

In addition to the direct road building done by the United States under contract, grants of land have from time to time been made to States in aid of road building, and the labor of United States troops has been employed in the work. The troops when so engaged in the early days were given an extra daily allowance of fifteen cents in money and a gill of whisky.

Returning to road building by the States, there is wide variation in their systems of legislation for this purpose, but a great amount of road building is going on in a miscellaneous way and much valuable knowledge is being developed.

Naturally the first method considered in most States is the building of State roads, somewhat as Massachusetts has begun. This plan has met with little favor, however, in other States, and it is feared that local jealousies will prevent any good, practical results under this method.

It is impossible for the State to build any large proportion of the roads that will be desired, and the people who are disappointed in getting the accommodation hoped for will soon be in the majority and the State appropriations be liable to be cut off.

A plan, which came near being adopted in New York State, of connecting all the county seats by a network of roads is apparently more fair than one which leaves a State commission to make a selection of those lines which seem to it most important; but this, again, is open to the objection that county seats are frequently not centers of business or travel, and long stretches of useless road would be built, while many business centers which are not county seats would fail to be accommodated. The same money spent in constructing the same length of road in each county, but so located as to radiate from shipping points and other business centers and to connect towns and villages not joined by railroad, would be of much greater benefit; and if the States' contributions were generally used, as they are beginning to be in New Jersey, to stimulate local effort and induce the expenditure of twice or thrice as much money by counties, towns, and neighborhoods, the benefit would be much greater still, while all ground for local jealousies would be removed, following the rule of "first come, first served," and helping those first who are first ready to help themselves. The offer of State aid, moreover, induces more or less of a scramble for its benefits and does more to agitate the public mind on this subject than any other method

of procedure. In New Jersey farmers who were opposed to the bare idea of road improvement a few years ago are among the most anxious to have it brought to their own neighborhoods.

The State aid roads, being widely scattered, form numerous centers of education, and soon the whole State will be ready for more expeditious measures of road improvement. This effect is not bounded by State lines. People are coming from other States to see what is being done in New Jersey, and they return to spread the news wherever they go that farmers are prospering, even in the midst of these hard times, solely by reason of having good roads in place of bad ones.

At my suggestion a committee of the New York State Legislature, together with members of the boards of supervisors, numbering nearly one hundred, visited some of the State aid roads in New Jersey last spring, and when they returned home they passed a bill for State aid through the Lower House of the Legislature by a majority of four to one.

Another committee from a county in North Carolina visited New Jersey, and on their return home the county entered at once upon a general scheme of road improvement.

These visible effects of practical demonstration have led me to search constantly for any available means of starting road improvement regardless of its being the best means possible. It is almost useless to carry on a campaign of education by mere talk and literature without something in the way of practical illustration and proof, hence I have endeavored to encourage every plan that leads to practical and present road building. The times are most unfavorable to any method which involves an increase of direct taxation, and in most rural localities there is an insuperable opposition to the issuance of bonds, notwithstanding that all those counties and townships which have heretofore borrowed money for road building have found their property values increase so rapidly by the influx of outside capital that their rate of taxation has been diminished instead of increased.

There are, however, a few places where the direct tax method is being employed and a considerable number where counties are issuing bonds — notably in the first case, the town of Canandaigua in the State of New York; and in the second case, the County of Morris in the State of New Jersey. Morris County has lately borrowed $350,000 at less than four per cent. interest, and the town-

ships of the county will tax themselves for half as much more for a complete system of county roads. In Canandaigua township the property owners have paid an extra tax of $4,000 annually for several years, and are so well pleased with the result that they are likely to continue the tax until all their roads are macadamized.

The direct tax method must be slow in its results, and for a long time it will be unequal in its benefits, since large portions of a township must pay the additional tax for years before their own roads can be reached; moreover, they will meantime be actually injured by the advantage given to their competitors of better access to their markets.

The direct tax method tends to insure economy in construction, but by limiting the means it narrows the scope of improvement, and this in some cases almost fatally. In Canandaigua, for instance, the authorities were obliged to choose between macadamizing the roads and lowering their grades, which latter required relocating and cutting down the hills. Not feeling able to do both, they chose to macadamize the roads where they were, and while they have made a great improvement they have in some cases probably barred out a greater one forever, for when roads have been resurfaced at what appears to be a great expense it is extremely difficult to make any subsequent change in their location. Their ideas of economy, moreover, forbade the employment of an engineer, and though they have made excellent roads they would have done much better under scientific advice. The fact, however, that they have succeeded with only the ordinary educated farmer's knowledge of road building shows that engineers, to make themselves useful and requisite in the construction of ordinary country roads, must be prepared to adapt themselves to all conditions, and more especially must they know all the possible economies of road construction.

There is a constant apprehension in the rural mind that the employment of an engineer or an architect leads to needless expenditure, and unless engineers adapt themselves to the conditions existing they are liable to be left out in the great majority of plans for country road building, in which case both roads and engineers will suffer.

Country road building is the particular branch of the science and practice which I desire to develop, since my special function in the Department of Agriculture relates to the building of such roads

as distinct from city or suburban streets, and I am extremely anxious that engineers who are intending to devote themselves to road construction should be able to give the benefit of scientific knowledge to the building of improved roads even of the simplest and cheapest character. In my second lecture I will go more into detail in this direction.

Returning to road legislation and the definite question of ways and means, the county bonding laws passed by various States have been useless where they require a popular vote to authorize the issuance of bonds, and they have only been effective in a few cases in New Jersey and in some counties in other States where only the assent of a county board was required. It is very clear, then, that in no considerable part of the United States are the masses of the people educated up to the point of being willing to tax themselves or to borrow money to any great extent for the purpose of road building. In Missouri, where an active campaign for road improvement has been carried on for several years, the people have lately voted down by a large majority an amendment to the constitution merely permitting counties to vote a special tax for this purpose; yet while in no State nor scarcely in any county is there a sufficiently developed sentiment in favor of road building to secure a majority of votes for any extensive measure of practical improvement, yet in almost every county in every State there is some neighborhood far enough advanced to be ready to contribute a share towards the improvement of its own roads if the county and State will do the rest.

Apparently, then, this opens the only practicable way for immediate action in all the States, and legislation in favor of State aid to localities is becoming a favored scheme in the minds of the advocates of good roads everywhere. It is through State aid only that the cities and villages, which are generally quite ready to assist the farmers in road building, can make their assistance available.

In Ohio, Indiana, and some other Western States improved roads are built by assessing a part of the cost on a strip of one, two, or three miles in width on either side of the road and the balance upon the county at large, but this plan is not wholly just; in fact, the benefits of road improvement will rarely, if ever, be bounded by parallel lines.

Roads that are important enough to require systematic reconstruction will generally be such as radiate from railway stations or boat landings, market towns, county seats, or villages, and the district

benefited by each will widen rapidly as the distance from the common center increases. Taking the case of four main roads diverging from a railway station at right angles to each other, these roads at a distance of five miles will be seven miles apart, and the benefit district of each will be a triangle, with its apex at the station and a width of seven miles at the base. The bounds of the district, moreover, will be modified by many such natural obstacles as streams, swamps, hills, valleys, etc., which will divert travel to or from a particular road, or by artificial conditions, like the location of factories, creameries, grain elevators, schools, or churches. All these conditions, however, are susceptible of a fairly exact determination, and the benefit district of a road can be almost as accurately defined as the drainage area of a stream. When it is so defined such a district forms an ideal unit of action for road improvement, the interests of all its people are identical, though unequal, and the share of expense each one ought to bear can be safely left to the commissioners charged with its assessment. (New Jersey State aid law.)

The bill passed by the Assembly of the State of New York divided the total cost of roads built with State aid into three equal portions, one to be paid by the State, one by the county, and one by the benefit district, except in cases where the benefit district was peculiarly restricted and its area fell below an average of one mile wide on each side of the road, in which case its share was to be scaled down proportionately to its decrease in area, but not in any case below ten per cent. of the whole. The local assessment upon the benefit district was made payable in ten annual installments, with interest, the county meanwhile advancing the money. In the case of roads built from local materials, as in Canandaigua, and made with single track of stone and a parallel track of earth, as is now considered the best practice for farming districts, the total cost will approximate $4 per rod in length, or $1 per acre of the two square miles of area benefited by each mile of road, of which only one third, or thirty-three and one third cents per acre, falls upon this area; this divided over ten years amounts, with interest, to only four cents per acre annually.

The customary tax for road repairs amounts to about ten cents per acre annually, and if the increase of four cents per acre is found too heavy the repairs tax might safely be reduced for ten years to six cents per acre, leaving the total tax no greater than at present. The roads in Canandaigua have cost about $900 per mile, but it would have

been better economy to have added a few hundred dollars to this cost. In my second lecture I will give some details of their construction.

I have said enough on the subject, perhaps, to show that through the application of State aid good permanent roads can be built without increasing the burdens of the farmer through local taxation, and all experience has shown that the expense to the State and county is much more than balanced by the increase in taxable values of the districts through which the roads are built.

Another method of road building which is coming much into vogue, especially in the Southern States, is that of using convict labor for the purpose, and so much is being accomplished in this direction that it is worth while to give careful consideration to its details.

There are three sides to the question of working convicts on the highways, or rather two sides and a broad middle ground.

The negative side is taken by the New York Prison Association and by penologists generally. The reasons advanced in opposition to the plan are that honest labor would be interfered with; that a large body of keepers would be required at great expense; that there would be a constant necessity for shooting convicts in order to prevent escapes; that in many cases the prejudice against convict labor would require a military force to protect convicts thus employed; and that it would be demoralizing to the convicts themselves to employ them in public places.

This is a view of the question natural to men whose minds are fixed on benefiting society by the reformation of criminals. Opposed to it is the opinion of many good citizens who seek the public advantage in other ways, and especially in the direction of improved means of communication, and who see in the convicts now idle in our jails and prisons a labor force sufficient to mend all the roads in the country, if it could be so applied, and which they believe could be so applied without prejudice to free labor. The advocates of the convict road work insist further that the outdoor life and exercise afforded by such employment would benefit the health and morals of the prisoners.

In the vicinity of Charlotte, North Carolina, convicts have built miles of substantial roads, and with such satisfaction to the people that the special law under which it was done is now being extended to other counties. In other Southern States where the convict lease system still prevails it is clear that a transfer of the prisoners from

irresponsible and often inhumane private employment to the care of States or counties would be a saving kindness to them and would benefit the entire community.

Some of the apprehensions of the New York Prison Association do not appear to have been well founded. The New York Legislature passed a bill providing for the employment of convict labor of the roads of the State, in spite of the protest of the association, and a very satisfactory experiment was made at Clinton Prison. There was no interference with the convicts by the citizens, except in two cases where intoxicated men offered them liquor; no apparent demoralizing effect on the prisoners or the public; no shooting of convicts, and only three men attempted to escape. In his report on the subject the warden of the prison concludes as follows: "That a limited number of convicts can be worked successfully is now an established fact."

On the other hand, when we examine the warden's financial statement we find but little, if any, economy in the use of convicts as compared with the employment of free laborers for the same work. The cost of maintenance, of guards, and of the search for escaped convicts was equal to ninety-one cents for each day's labor done, which, considering the comparative efficiency of such labor, is very near its full value, their day's work being only eight hours. Again, it may be safely predicted that when road making becomes a great business in the country the introduction of labor-saving appliances will do away with a large share of the hand labor now required in laying a stone or gravel road. The material being generally transported by railroads will then be transferred to wagons without shoveling, and from the wagons will be mechanically spread in its place, so that almost nothing will be left for convicts to do on the line of the road.

These considerations strengthen the position of those who hold the middle ground of the question, which is that State prisoners should be employed wholly in the preparation of road material and in places where they can be as easily guarded and secluded as in the prisons. The plan proposed for this is in substance as follows: First, for the State to buy some of the territory which contains the best rock within its limits; second, to make the necessary railroad connections, having first secured the permanent agreements of all its leading railroad companies to carry road material at the cost of hauling, on condition, if required, of the State furnishing to them a certain amount of track ballast free of charge or at the cost price; third, having erected the

necessary buildings and provided the best machinery for quarrying and crushing rock, to bring all able-bodied State convicts and put them at this work; fourth, the counties to put their jail prisoners and tramps at the work of grading, draining, and preparing the road for macadamizing; fifth, the State to furnish broken stone free on board cars as its contribution to road improvement.

The cost to the State in addition to the maintenance and guarding of the convicts would be only that of fuel and oil, explosives, and use of machinery, or, according to the Massachusetts Commission Report, six and eight tenths cents per cubic yard of broken stone, amounting for the twelve hundred yards required to lay a mile of single-track road nine feet wide and eight deep to $81.60.

The remaining cost would be the railroad freight, amounting for an average distance of a hundred miles to not more than twenty-eight cents per yard, or $336 per mile; the wagon-haul, averaging possibly two and a half miles, thirty cents per yard, or $360 per mile; and the rolling, superintendence, and incidentals (not including engineering, which would be a general county charge), ten cents per cubic yard — making the total local cost sixty-eight cents per cubic yard, or $815 per mile.

This plan would bring the expense of road improvement so low that no elaborate scheme of taxation or borrowing would be necessary, and all its benefits could be speedily and universally realized. The best plan for carrying it out would perhaps be to let the "benefit district," as heretofore defined, pay one third of the cost by installments and the township one third, the county to pay the remainder and to advance the amount for the district, with a rebate or discount to all individuals who might prefer to pay in cash, so that no one would be put in debt against his will. The total cost to the district on this basis of division would be $272 per mile, or twenty-one cents per acre.

The growth of the road movement in North Carolina is unquestionably due to the use of convicts. Indeed, this use has in the majority of cases been the most important factor in deciding the counties of that State to vote a tax for the improvement of the public roads. The result of the experiments in North Carolina has been altogether favorable to the system, both in point of efficiency and in economy and in the health of the convicts. In Lenoir County only short-term convicts are employed. They are carefully described and photo-

graphed, and offered certain inducements in the way of reward or shortening of term if they remain at their post and faithfully discharge their duties. With this precaution they are employed on the public road very much as hired laborers would be, under the control of a superintendent, but without a guard, and they are allowed to remain at their homes from Saturday night until Monday morning. This novel experiment has been in operation a year, and not a convict has attempted to escape. (Cost of maintenance reduced from thirty cents to twenty-four cents per day while so employed.)

Many of the States are now arranging to establish supply camps for road material at which State convicts can be worked under proper restrictions. In California especially the State Prison grounds contain an excellent vein of trap rock — the very best of road material — and abundant water power, with the necessary machinery for moving and crushing rock. There are seven hundred or eight hundred convicts in the prison. The prison authorities find that they can prepare road material and put it on the cars for twenty cents a cubic yard and pay all of the expenses of the prison out of the receipts.

Many railroads have already offered to transport material for the bare cost of train service, and probably most of the roads in the country would be willing to make such an arrangement, for they are naturally interested in the improvement of the highways. Their deep concern in the condition of its highway is universally recognized; it was particularly well expressed at the Michigan Engineers' Convention by Mr. E. W. Muenscher, Chief Engineer of the M. & G. R. Railway, who said: "No interest in the State of Michigan would be more benefited by good roads than the railroads. During a large part of the year much of their rolling stock is lying idle because farmers cannot bring their produce to the station. At other times they cannot get cars enough to haul away this produce, and the sidings, elevators, and warehouses are gorged to overflowing; extra forces must be employed; men in other lines of traffic who need cars are denied, and general disturbance of business, delay, and loss follow. Good roads would distribute this business more uniformly over the year, to the mutual advantage of the companies and their patrons, to say nothing of the increase of population and production and prosperity which would follow."

In the State of Kentucky very excellent roads have been built under special laws, permitting counties to contribute $1,000 per mile

to the construction of stone roads of specified details, and the State has now a larger mileage of good roads in proportion to its population than any other in the United States.

The various methods in practice comprise, therefore, first, direct State road building, as in Massachusetts and some of the Western mountain States; second, State aid, as in New Jersey; third, county road building; fourth, county aid to local contribution; fifth, convict labor; sixth, direct taxation; seventh, assessment of benefit strips; eighth, township bonding, as in Pennsylvania. Under these various methods roads enough will undoubtedly be built so much better than those at present existing in this country as to pave the way for building better and more costly roads in the future, and while I urge on young engineers to be prepared to build these cheaper roads chiefly for their educational advantages to the public, I do not by any means desire to lower the ultimate standard of road building. The great highways of the future will undoubtedly be better structures than anything in the present or the past and fully worth a trained engineer's most earnest study and attention. Undoubtedly the wearing surfaces of stone or asphalt will be replaced by flat steel rails suited to all vehicles and laid level with the roadway, so that wheels will pass on to or off them with slight difficulty, the outer edge being raised only enough to give a gentle guidance to the wheels.

There is no more economy in running a wagon over a rough surface than there would be in running a railway train, and the saving in wear on roads of heavy travel with the present low price of steel would alone be more than the difference in cost, while the saving in traction would be from fifty to eighty per cent.

These great highways will connect all the large cities and will be crowded with vehicles of kinds now seen only in exhibitions or on trial trips. One need not look far into the future to see horses superseded for all road uses except pleasure driving, and largely for that. In the race for automobile vehicles between Paris and Rouen last July over a hundred vehicles of different descriptions were entered. Those driven by electricity were barred for the want of facilities for recharging. In the next race these vehicles will be provided for, and with the steady diminution in weight required for storage batteries they will undoubtedly be a favorite class.

The recent extended development of cheaper water powers, especially in this country, together with the successful transmission of

power by electricity, will furnish an abundant supply of motive power for such vehicles on all the great highways at a cost far below that of animal power.

The city of Augusta, Georgia, furnishes water power at the rate of $5.50 per horse power per annum, and makes money thereby. This is at the rate of one and three quarters cents per day. Supposing this to be doubled for transmutation and doubled again for transmission and doubled yet again for profit, it would still furnish power on draught along the public roads for $1 per week per horse power.

One of the latest of the electrical carriages for two persons weighs but little over one ton, including passengers and battery. One-horse power will move this vehicle over a good stone road at fifteen miles per hour, or a thousand miles in a week by daylight. This gives a journey of a thousand miles for two persons for $1, or about one fortieth the cost of railway travel.

This is progress enough in the art of transportation to suffice for a few years at least. The great masters of aërostation are succeeding so well in the art of flying that if they do equally well in the art of alighting they may sometime do away with the need of roads altogether, but until then we shall keep on improving roads and vehicles till we make traveling as near like flying as possible.

REVIEW OF AMERICAN CHEMICAL RESEARCH.

ARTHUR A. NOYES, EDITOR.

THE purpose of this publication, which is hereafter to appear serially in this journal, is to present in a concise form a review as complete as possible of all original work having a chemical bearing published in the United States after the beginning of the year 1895. It is believed that such a compilation will prove of more than usual value in the case of the research work of this country by reason of the fact that so large a proportion of it is published in other than chemical journals, and thus fails to become incorporated with the rest of the science, and also because the abstracts of American chemical literature published in foreign journals are very incomplete.

The execution of the plan has been made possible by the cordial coöperation of members of the instructing staff of the Institute of Technology. The following is a list of the present abstracters:

C. W. Andrews: Chemistry of Sugar. W. O. Crosby: Geological and Mineralogical Chemistry. A. H. Gill: Gas Analysis, Fuels, Oils, and Apparatus. H. M. Goodwin: Physical Chemistry. H. O. Hofman: Metallurgical Chemistry and Assaying. A. A. Noyes: General and Organic Chemistry. E. H. Richards: Sanitary and Agricultural Chemistry. J. W. Smith: Dyeing and Bleaching. H. P. Talbot: Inorganic and Analytical Chemistry. F. W. Thorp: Technical Chemistry.

The abbreviations of the names of journals are those recommended by the Committee on Indexing Chemical Literature of the American Association for the Advancement of Science (*Proceedings*, **36**, 45).

GENERAL AND PHYSICAL CHEMISTRY.

The Effect of Hydrolysis upon Reaction Velocities. BY F. L. KORTRIGHT. *Am. Chem. J.*, **17**, 116–122. — The author points out that, in the case of reactions between substances partially hydrolyzed, not the total quantity, but only the non-hydrolyzed electrolytically dissociated portion of each substance is to be regarded as its active mass, and applies this undoubtedly correct principle in order to explain the variations of the reaction constants calculated by Kahlenberg (*J. Am. Chem. Soc.*, **16**, 314) from his measurements of the velocity of the reaction between stannous and ferric

chlorides. The author's explanation involves, however, three further assumptions: 1. That stannous and ferric chlorides are *equally* hydrolyzed. 2. That the hydrolysis in neutral 0.05 normal solution amounts to more than 40 per cent. 3. That the absolute quantity of the hydrolyzed salts remains unchanged throughout the course of the reaction. In the complete absence of any knowledge in regard to it, the first assumption must, from the laws of chance, be considered very improbable, for there are not even analogies between stannous and ferric salts to justify it. The second assumption is disproved by the freezing point determinations of ferric chloride solution recently published by the abstracter (*Ztschr. physikal. Chem.*, **16**, 558), which gave for the molecular lowering of that salt in 0.075 molecular solution 3.42 times the normal value; while, if hydrolysis took place to any considerable extent, the value would have been much larger (being six to seven times the normal for complete hydrolysis and four times the normal for no hydrolysis and complete dissociation). And, finally, the third assumption is in direct contradiction with the laws of mass action which it is the purpose of the article to elucidate; for the hydrolyzed quantity of the salts must diminish as the electrolytically dissociated amount diminishes, as a consequence of the equilibrium condition between them. The fact, therefore, that the author's formula represents Kahlenberg's results in a satisfactory manner has no theoretical significance, but is merely a consequence of the mathematical principle that an empirical formula with two arbitrary constants can always be made to express results more closely than one with a single constant. The true explanation of the deviations observed by Kahlenberg is, as the abstracter has shown, to be found in the fact that the reaction is of the third order, and should be represented by the differential equation of that order, not by that of the second. (Compare *Ztschr. physikal. Chem.*, **16**, 546.) It is much to be regretted that the theory of the velocity of chemical change originally proposed by van't Hoff is so often completely ignored by authors writing on the subject; for it is certainly still an open question whether the order of a reaction is determined by the number of *molecules* or by the number of *substances* taking part in it.

A. A. Noyes.

On the Influence of Magnetism on Chemical Action. By F. A. Wolff, Jr. *Am. Chem. J.*, **17**, 122–138.— The author describes some experiments made with the purpose of explaining the phenomena previously observed by Remsen (*Am. Chem. J.*, **3**, 157) in precipitating copper from a solution of its sulphate on a magnetized iron plate. The phenomena consist (1) of rotation set up in the solution; (2) of unequal deposition of copper on different parts of the plate, there being no deposit on the outlines of the magnetic poles; and (3) of deposition of the copper in ridges at right angles to the lines of force. The conclusions reached are that magnetism has no direct influence on the chemical action between the iron and copper sulphate, but that it causes a concentration of the resulting iron salt in the strongest parts of the field, and that to this effect and the electric currents arising from it the phenomena in question are to be attributed. The author also states that the earlier experiments of Hunt indicating an effect of magnetism on various other chemical reactions were repeated both by Professor Remsen and himself mostly with negative results and without obtaining any evidence of a magnetic influence.

A. A. Noyes.

A Redetermination of the Atomic Weight of Yttrium. By HARRY C. JONES. *Am. Chem. J.*, 17, 154–164.—The yttria employed was prepared by Professor Rowland by fractional precipitation of the earthy metals with potassium ferrocyanide as previously described. (*Chem. News*, 70, 68.) The ratio $Y_2O_3 : Y_2(SO_4)_3$ was determined both by treating the oxide with dilute sulphuric acid, evaporating, and drying at a temperature somewhat above the boiling point of the acid, and also by igniting the crystallized sulphate over the blast lamp. Ten determinations by the first method gave for the atomic weight the mean value: 88.94, and an equal number by the second method: 88.97, the maximum and minimum values being 89.05 and 88.89 respectively. The result is slightly lower than that obtained by Clève: 89.1 (*Bul. Soc. chim.*, 39, 120) with yttria fractionated by oxalic acid, and confirms the usefulness of the easier method of separation with potassium ferrocyanide.

A. A. NOYES.

A Modified Arrangement of the Elements under the Natural Law. By F. P. VENABLE. *J. Am. Chem. Soc.*, 17, 75–84.—The purpose of the modifications is to make the Periodic Law more readily intelligible to students and more satisfactory as a basis of presentation of chemical facts. The first suggestion is that the expression "periodic functions" be omitted in the statement of the law itself, so that it shall read: "The properties of the elements are dependent upon and determined by the atomic weights." This the author considers the essential part of the Periodic Law. To the abstracter it seems a mere platitude which deprives the law of its whole real significance, which lies in the very fact of periodicity. It is, of course, not necessary to use the expression "periodic functions," which is too indefinite as well as mathematical. The abstracter employs the following general statement: "If the elements are arranged in the order of their atomic weights, there is found to be a *progressive* change in their properties, and a *recurrence of similar properties* at certain definite intervals in the values of their atomic weights." Moreover, the arrangement of the elements proposed by the author is influenced by this misconception, being in reality based primarily on similarity of properties in general, not on the values of the atomic weights. Therefore, whatever may be its advantages as a system of classification for certain purposes, it cannot be regarded as a satisfactory expression of the truths contained in the Periodic Law. For the details of the arrangement reference must be made to the original article.

A. A. NOYES.

Report of Committee on Atomic Weights Published during 1894. By F. W. CLARKE. *J. Am. Chem. Soc.*, 17, 201–212.—A summary of the atomic weight determinations published during the preceding year, the mean results of which are given below (O = 16):

Hydrogen (Thomsen, Ztschr. physikal. Chem., 17, 398, 726)	0.999
Strontium (Richards, Proc. Am. Acad., 1894, 369)	87.66
Barium (Richards, Proc. Am. Acad., 29, 59)	137.44
Cobalt (Winkler, Ztschr. anorg. Chem., 8, 1)	59.52
Nickel (Winkler, Ztschr. anorg. Chem., 8, 1)	58.86
Palladium (Keiser, Breed, Am. Chem. J., 16, 20)	106.51
Tungsten (Pennington, Smith)	184.92
" (Smith, Desi)	184.70
Thallium (Wells, Penfield, Am. J. Sci., 47, 466)	204.47
Bismuth (Schneider, J. prakt. Chem., 50, 461)	208.05
Tin (Schmidt, Ber., 27, 2743)	118.48

The article closes with a revised table of atomic weights.

A. A. NOYES.

On the Application of the Schroeder-Le Chatelier Law of Solubility to Solutions of Salts in Organic Liquids. By C. E. Linebarger. *Am. J. Sci.*, **49**, 48–53. — The author tests the applicability of this law, according to which "the solubilities at equal intervals from the temperatures of fusion for different solid bodies and in different solvents are the same," to solutions of inorganic salts in organic liquids. He uses for this purpose data furnished by Etard and Arctowski, and experiments of his own on the solubility of cadmium iodide, mercuric chloride, and silver nitrate in benzene. Although the law was found by its propounders to be satisfactorily confirmed by certain organic bodies dissolved in chemically similar solvents, the author finds that this is not even approximately the case with inorganic bodies, from which he concludes that the "law" is not general, but applicable only to certain special classes of bodies.

H. M. Goodwin.

Determination of the Electric Conductivity of Certain Salt Solutions. By Albert C. MacGregory. *Phys. Review*, **2**, 361–372. — The electrical conductivity of a number of salts of the alkali-earth metals was determined in aqueous solution by the well-known method of Kohlrausch. As the results are of great value for determining the degree of the dissociation of the salts, they are given below in full for dilutions of ten liters and over.

m	$CaSO_4$.	$CaCl_2$.	CaN_2O_6.	$Ca(C_2H_3O_2)_2$.	$SrCl_2$.	SrN_2O_6.	$Sr(C_2H_3O_2)_2$.	$Ba(C_2H_3O_2)_2$.	$AgC_2H_3O_2$.	$K_2C_4O_6$.
0.0001	1079.0	1078.9	1094.1	725.6	1124.7	1043.5	769.8	770.7	797.2	1171.5
0.0002	....	1066.2	1084.5	708.8	1109.4	1035.2	768.3	770.2	801.1	1148.9
0.0005	1025.0	....	....	....	....	....	....	....	....	....
0.0006	....	1054.2	1061.0	693.4	1081.9	1014.2	762.7	758.9	801.8	1145.7
0.001	977.1	1042.3	1050.5	684.7	1069.4	1004.7	756.8	750.1	799.2	1137.4
0.002	....	1035.2	1032.3	671.8	1051.8	985.8	737.4	737.3	....	1123.9
0.005	804.6	....	....	....	....	....	....	....	777.4	....
0.006	....	986.7	992.0	636.8	1009.9	943.3	708.8	703.5	....	1080.2
0.01	719.8	964.7	963.3	616 3	986.6	920.0	687.5	682 8	750.4	1054.7
0.05	....	868.3	853.2	519.4	880.9	801.8	587.3	587.8	....	938.7
0.1	....	821.8	794.8	466.4	849.2	746.3	532.9	539.1	....	883.9

The numbers in the column headed m denote the concentration in gram *equivalents* per liter. The remaining columns contain the corresponding equivalent conductivity multiplied by 10^8 at 18°.

This list makes more complete our hitherto rather fragmentary data on the electrical conductivity of this class of salts, Kohlrausch's measurements being confined (barium salts excepted) to the more concentrated solutions. The only anomaly observed was in the case of silver acetate, whose molecular conductivity reached a maximum at a dilution of 0.0006 gram equivalents per liter. It seems to the abstracter that this is probably to be explained by hydrolysis of the salt.

H. M. Goodwin.

Surface Tension of Water at Temperatures Below Zero Degree Centigrade. By W. J. Humphreys and J. F. Mohler. *Phys. Review*, 2, 387–391. — The surface tension of water was determined at temperatures varying from + 18.5° C. to — 8.3° C. by a slightly modified form of the capillary tube method, by which the meniscus was always brought to the same point in the capillary. The well established linear decrease of surface tension with the temperature was found to hold without discontinuity between these limits, and is expressed by the equation $T_t = T_o (1 - 0.002014t)$. The constant agrees well with that found by other observers for higher temperatures.

H. M. Goodwin.

Preliminary Table of Solar Spectrum Wave-Lengths. By Henry A. Rowland. *Astrophys. J.*, 1, 29–46, 131–145, 222–231. The above articles are the first of a series which when completed will contain the invaluable result of the author's exhaustive study of the solar spectrum. The author has with his unsurpassed facilities now photographed the spectrum of every known element (with the exception of gallium) in connection with the solar spectrum. The laborious comparison and complete identification of the lines of the solar spectrum with the spectra of the elements must still remain the work of years; much has, however, already been accomplished in this direction, the measurement of the wave-lengths of the solar lines being now nearly completed. The tables now published contain the wave-lengths of the solar lines, the element or elements to which they are due when known, and estimates of the intensity and remarks on the character of the lines. It is intended to add to this table from time to time as the work of comparison progresses until a standard list of the lines of the solar spectrum with all the elements to which they are due is finally published.

H. M. Goodwin.

A Theory of Electrolysis. By Alfred H. Bucherer. *Electrical World*, 25, 138–140. — After pointing out the "enormity" of the conception of charged ions assumed by Arrhenius' dissociation theory, the author develops a new theory of the voltaic cell based on the laws of mass action and on the assumption that electrolytes are in solution dissociated into *uncharged ions*. The theory assumes, for example, that a hydrochloric acid solution contains uncharged chlorine ions, chlorine atoms, uncharged hydrogen ions, and hydrogen molecules. As the abstracter is unable to follow the author's reasoning in the further development of his remarkable "theory," a more detailed review is impossible.

H. M. Goodwin.

Inorganic Chemistry.

Researches on the Complex Inorganic Acids. By Wolcott Gibbs. *Proc. Am. Acad.*, 30, 251–282; *Am. Chem. J.*, 17, 73–91, 167–185. — The first section of this paper forms the supplement to a preliminary article published in 1877 by the author on the alkaline platino-tungstates and platino-molybdates. These salts are formed when platinic hydrate is boiled with solutions of normal or acid tungstates or molybdates, or when platinic chloride is added to boiling strongly alkaline solutions of normal tungstates

or molybdates. Considerable quantities of platinic oxide pass into solution, and the following well-characterized salts are obtained:

12 : 5 sodium tungstate gives $10WO_3.PtO_2.6Na_2O + 28Aq.$
Normal sodium tungstate gives $20WO_3.PtO_2.9Na_2O + 58Aq$,
together with $30WO_3.2PtO_2.15Na_2O + 89Aq.$
10 : 4 sodium tungstate gives $30WO_3.PtO_2.12Na_2O + 72Aq.$
14 : 6 ammonium molybdate gives $8MoO_3.2PtO_2.3(NH_4)_2O + 12Aq$,
and $4MoO_3.2PtO_2\,2(NH_4)_2O. + 19Aq.$
Normal potassium molybdate gives $60MoO_3.PtO_2.10K_2O. + 40Aq.$

It has long been known that pyrophosphates of the heavy metals are frequently soluble in sodium pyrophosphate solution with the formation of double salts in which the heavy metal no longer exhibits its characteristic reactions with reagents. Admitting that the heavy metal in these salts forms part of an electro-negative radical, experiments were made to ascertain whether in the case of such mangano-alkali salts the electro-negative groups are transferable to salts of "complex acids," and, if so, whether the latter compounds differ from the ordinary pyrophospho-tungstates and pyrophospho-molybdates. No satisfactory evidence of such a difference was found, although several well-defined mangano salts, of which the compounds $22MoO_3.2P_2O_5.7MnO.9Na_2O + 57Aq.$ and $14WO_3.6Na_2O + P_2O_5Mn_3 + 36Aq$ may be selected as examples, were prepared and studied.

When a solution of auro-sodium pyrophosphate, P_2O_7AuNa, is treated with ammonia an auramin pyrophosphate of sodium — $14Au_2O_3.6P_2O_5.14NH_3.3Na_2O + 24Aq.$ — is formed, which explodes with violence at 170°. Boiled with 14 : 6 ammonium molybdate this auramin pyrophosphate gives a slightly explosive auramin pyrophospho-molybdate, $12Au_2O_3.3MoO_3.7P_2O_5.24NH_3 + 21Aq.$ Auro-pyrophospho-molybdates are also described.

Molybdico-tungstates having the general formula $12WO_3.MoO_2.5M'_2O$ seem to be formed when $Mo(OH)_4$ is dissolved in 12 : 5 alkali-tungstates. These salts absorb oxygen from the air with avidity. Uranoso-tungstates, $8WO_3.6UO_2.9K_2O + 34Aq$ and $8WO_3.6UO_2.12Na_2O + 25Aq$, a silico-molybdate, $12MoO_3.SiO_2.2(NH_4)_2O + 5Aq$, and a selenoso-molybdate, $17MoO_3.6SeO_2.5K_2O$, were likewise obtained, while the probable existence of tellurosо-molybdates and tungstates and of cerico-molybdates is to be assumed in consequence of certain tentative experiments.

In earlier installments of his extensive investigation on "complex inorganic acids" Dr. Gibbs has endeavored to establish the existence of a special class of meta-tungstates, whose lowest term is represented by the formula $4WO_3.RO$ and the highest by $24WO_3.11R_2O$. The highest term actually described by him previous to the present article appeared to be $16WO_3.3Na_2O.4(NH_4)_2O + 18Aq$, but a new analysis of this salt makes it correspond somewhat better with the formula $24WO_3.5Na_2O.6(NH_4)_2O + 27Aq.$ The paper closes with the description of a new phospho-tungstate, $20WO_3.P_2O_5.Na_2O.2H_2O + 19Aq.$

S. P. MULLIKEN.

The Action of Metals on Nitric Acid. By G. O. HIGLEY. *Am. Chem. J.*, 17, 18–27. — The paper, which is one of a series, discusses the reduction of nitric acid by copper and lead. The apparatus and procedure employed are fully described, the results from which may be summarized as follows: When copper is the reducing agent no nitrogen appears among the reduction products, whatever the concentration of the nitric acid; no

nitrous oxide is obtained with acid solutions of greater specific gravity than 1.15, but the quantity increases with greater dilution until a specific gravity 1.10 is reached, then it slightly decreases; nitric oxide is not found with acids of a specific gravity above 1.25; nitrogen dioxide and trioxide in varying proportions are the sole products of reduction of nitric acid of a specific gravity 1.30 to 1.40. The experiments made with lead were confined to acid with specific gravities 1.05 to 1.35; a more concentrated acid failed to dissolve the coating of lead nitrate. The decomposition products are, in general, the same as with copper, but the lead acts more readily than the copper, producing with equal concentration of acid relatively more nitrous oxide and less of the higher oxides of nitrogen. The author suggests that the results obtained favor the assumption of a direct deoxidation rather than one taking place through the intervention of nascent hydrogen.

H. P. TALBOT.

The Combination of Sulphur with Iodine. By C. E. LINEBARGER. *Am. Chem. J.*, 17, 33–59. — Reference must be made to the original article for a description of the experimental work and for the detailed historical sketch of earlier investigations. The author's experiments upon the fusion of iodine and sulphur, on their behavior in carbon bisulphide solution, and on double decompositions of their compounds indicate that but one definite chemical compound is formed; this compound has the molecular formula S_2I_2, and melts at 66.1°–66.2°. It is not a stable combination, but is analogous to those bodies which are denominated "molecular compounds."

H. P. TALBOT.

A Laboratory Method for the Preparation of Potassium Ferricyanide. By M. S. WALKER. *Am. Chem. J.*, 17, 68. — The author recommends the use of potassium permanganate to oxidize ferrocyanide to ferricyanide instead of bromine or chlorine. The permanganate is used in hydrochloric acid solution (8 cc. of concentrated acid in 200 cc. of solution), which is subsequently neutralized by barium carbonate. The first crop of crystals only is used.

H. P. TALBOT.

On the Cupriammonium Double Salts. By T. W. RICHARDS AND A. H. WHITRIDGE. *Am. Chem. J.*, 17, 145–152. — The paper is a continuation of a previous article (*Am. Chem. J.*, 15, 642), dealing with the same class of bodies. The following new compounds are described, with methods of preparation and results of analysis: Cupriammonium formichloride $[Cu(NH_3)_2ClCHO_2]$, blue prismatic crystals, permanent in dry air, but decomposed by water; ammon-cupriammonium acetobromide $[Cu(NH_3)_3BrC_2H_3O_2.H_2O.]$, brilliant blue flakes, slightly soluble in alcohol, and decomposed by water; cupriammonium proprionobromide $[Cu(NH_3)_2Br.C_2H_5O_3]$, blue prismatic crystals, permanent in the air; cupriammonium lactobromide $[Cu(NH_3)_2BrC_3H_5O_3]$, blue crystals, with a faint purple tinge, permanent in the air, but decomposed by water; and cupriammonium lactochloride $[Cu(NH_3)_2ClC_3H_5O_3]$, crystals of a lighter blue than the lactobromide, but otherwise similar in properties. The corresponding compounds of butyric acid could not be prepared. The authors will continue their investigations, and will include the corresponding amine derivatives.

H. P. TALBOT.

Cupric Hydride. By E. J. Bartlett and W. H. Merrill. *Am. Chem. J.*, 17, 185–189. — The so-called "copper-sponge," resulting from the action of hypophosphorous acid upon copper sulphate, is found to oxidize the hypophosphorous acid to phosphorous acid with the evolution of hydrogen, the action continuing until the former acid is exhausted. Metallic copper in different forms fails to exert this action, while copper oxide reduced in hydrogen reacts in the same way as the copper sponge. An analysis of the sponge, as well as the reduction product from the copper oxide in hydrogen, shows the existence of a cupric hydride, CuH_2, in each case. This hydride in the spongy condition is reddish brown, but changes to a chocolate when boiled or dried. It reacts with hypophosphorous acid only in the spongy form; it is unchanged at temperatures above 100° C. until the copper begins to oxidize, and dissolves in acids to form cupric salts with the evolution of hydrogen. The authors assume that the oxidation of the hypophosphorous acid is brought about by the decomposition of a molecule of water under the influence of the cupric hydride. It is probable that the efficiency of Gladstone and Tribe's copper-zinc couple (*J. Chem. Soc.*, 33, 308,) particularly after ignition in hydrogen, is influenced by the formation of cupric hydride.

H. P. Talbot.

Action of Light on Lead Bromide. By R. S. Norris. *Am. Chem. J.*, 17, 189–191. Lead bromide when subjected to light in a finely pulverized condition, and in a layer sufficiently thin to be semi-transparent, was found to blacken. The darkened product upon solution in water acidulated with nitric acid left an amount of metallic lead equal to 1 per cent. of the original weight. The bromide had lost 2.4 per cent. bromine. In a layer one millimeter in thickness, exposed to sunlight for two weeks, a product of lighter shade resulted, which was entirely soluble in water acidulated with nitric acid. A sample of lead bromide, carefully prepared to insure purity, darkened rapidly in the light. This change took place less rapidly under water, but with equal rapidity whether in an atmosphere of oxygen or of hydrogen. The author assumes this to be an instance of simple dissociation, and proposes to continue his investigation to determine this point.

H. P. Talbot.

Some New Solvents for Perchromic Acid. By William M. Grosvenor, Jr. *J. Am. Chem. Soc.*, 17, 41–43.—A two per cent. solution of potassium dichromate, slightly acidified with sulphuric acid, was in each instance shaken with hydrogen peroxide together with the proposed solvent, and the mixture allowed to stand. Ethyl ether, valerianic ether, amyl alcohol, amyl chloride, the amyl ethers of formic, acetic, butyric, and valerianic acids, and the ethyl ether of acetic acid were all found to be solvents of perchromic acid, while the paraffine oils, benzene, toluene, carbon bisulphide, chloroform, carbon tetrachloride, nitrobenzene, aniline, castor oil, oil of wintergreen, and oil of bergamot, each failed to exert a solvent action. The solution in ethyl acetic ester proved to be the most stable.

H. P. Talbot.

On Certain Phenomena Observed in the Precipitation of Antimony from Potassium Antimonyl Tartrate. By J. H. Long. *J. Am. Chem. Soc.*, 17, 87–105. — Reference is made to previous articles by the author concerning the behavior of solutions of tartar emetic (*Am. J. Sci.*,

Oct., 1889, and Oct., 1890, and *J. Anal. Appl. Chem.*, 5, 152), in which it is shown that solutions of sulphates, chlorides, nitrates, and oxalates of the alkali metals when added to solutions of the antimony salt produce no precipitation even with elevation of temperature, while carbonates, acetates, phosphates, and sulphites do not cause immediate precipitation at low temperatures, but throw out the antimony in the form of hydrated oxide at higher temperatures. A similar behavior is noted toward solutions of borates, tungstates, and thiosulphates in the present paper.

For each test 5 grams of the tartrate were dissolved in 60 cc. of water at 20°, and to these solutions definite weights of borax in solution in 35 cc. of water at 20° were added. In each case a precipitate fell, which was removed by filtration, and the antimony remaining in solution was determined. The amount precipitated increased with the amount of borax, but was never complete. The author has studied the reaction with the aid of the polarimeter, and shows that marked changes take place within the solution before precipitation begins. The rotation constants for the tartrates have been previously determined by the author, as well as the influence of boracic acid upon these quantities, and from the optical behavior of the antimony solutions he concludes that the ultimate reaction which takes place is the following:

$$2KSbOC_4H_4O_6 + Na_2B_4O_7 + 6H_2O = 2KNaC_4H_4O_6 + Sb_2O_3 + 4H_3BO_3.$$

He suggests that it may take place in two steps:

$$2KSbOC_4H_4O_6 + Na_2B_4O_7 = 2KNaC_4H_4O_6 + (SbO)_2B_4O_7;$$
$$(SbO)_2B_4O_7 + 6H_2O + xH_2O = 4H_3BO_3 + Sb_2O_3.xH_2O.$$

The hydrated oxide may by loss of water gradually become less soluble and appear as a precipitate. The preliminary change takes place gradually, as indicated by decrease in rotary power of the solutions. — Tungstates show a behavior similar to that of the borates, while thiosulphates produce, after a time, a precipitate which is yellow when it first falls and gradually changes to a bright red. It is probably a hydrated sulphide, $2Sb_2S_3.H_2O$. The author suggests that this reaction may also take place in two steps:

$$2KSbOC_4H_4O_6 + Na_2S_2O_3 + H_2O = Sb_2O_3 + 2NaKC_4H_4O_6 + H_2S_2O_3;$$
$$Sb_2O_3 + 2H_2S_2O_3 = Sb_2S_3 + 2H_2O + SO_2 + O_5,$$

the sulphur dioxide and oxygen being held to form polythionates.

No change in the specific rotation of the tartar emetic takes place until precipitation actually occurs, indicating that the molecule is not attacked until that point is reached. In this respect it differs from the borate and tungstate.

H. P. Talbot.

Chemical Analysis of Counterfeit Gold Dust. By V. L. Leighton and H. P. Cady. *Kansas University Quart.*, 3, 197–199. — The counterfeit gold dust, which closely resembled placer gold, was purchased some years ago by a Kansas bank, and was composed of malleable, irregular flakes with a coarse powder, which under the microscope was seen to be made up of fragments of chalcopyrite and turnings of an alloy. The flakes proved to be fragments of platinum, hammered and gold-plated. The alloy contained iron, silver, lead, platinum (17.6 per cent.), copper, and nickel. The specific gravity of the mixture was 14.43. The analytical procedure is described in detail.

H. P. Talbot.

Experiments on the Solubility of Platinum in Hydrochloric Acid. By V. L. Leighton and H. P. Cady. *Kansas University Quart.*, 3, 199–200. — The experiments were made upon pure, spongy platinum from ammonio-platinic chloride. The results were the following: By boiling the platinum with hydrochloric acid a loss of 2.1 per cent. by weight was incurred; in a sealed glass tube at 200° C., 4.52 per cent.; in a sealed glass tube and an atmosphere of hydrochloric acid at 300°–360° C., 10.5 per cent.; in a sealed tube in an atmosphere of hydrochloric acid, after removing the oxygen condensed on the surface of the platinum and at 300°–360° C., 2.25 per cent. The authors infer that at the higher temperature the hydrochloric acid is decomposed by the oxygen condensed on the surface of the platinum, with the formation of nascent chlorine.

H. P. Talbot.

Organic Chemistry.

On the Action of Chlorcarbonic Ester on Sodium Acetone. By Paul C. Freer. *Am. Chem. J.*, 17, 1–18. — The products of this reaction are investigated in order to establish the constitution of the sodium compound of acetone previously discovered by the author. Somewhat less than the theoretical quantity of chlorcarbonic ether is gradually added to small amounts of sodium acetone under ether in an atmosphere of hydrogen, and the mixture let stand ten days in a warm place. The solid product which separates consists of a mixture of sodium chloride with about 15 per cent. of sodium carbonate. The liquid product yields on distillation three principal fractions, boiling, respectively, below 110°, between 126° and 137°, and above 170°. The first consists largely of unchanged chlorcarbonic ether. The second is believed by the author to be a mixture composed mainly of isoacetone carbonic ether, $CH_2{:}C(CH_3).O.CO.OC_2H_5$, for the following reasons: The analysis of it yields values corresponding roughly to this formula. The vapor density also accords with it. The body does not react with phenyl hydrazine, hence it is not the isomeric acetoacetic ether. It is completely decomposed by barium hydrate or hydrochloric acid into carbonic acid, ethyl alcohol, isopropyl alcohol, and acetone; the amount of carbonic acid so obtained agrees well with the theory, and the amount of acetone exceeds 30 per cent. of the original liquid. The products of the action of phosphorus pentachloride upon it are 2-chlorpropene ($CH_3.CCl{:}CH_2$), ethyl chloride, phosgene, and carbonic diethyl ether. The author, therefore, concludes that sodium acetone must have the formula, $CH_3.CONa{:}CH_2$. The fraction boiling above 170° consists principally of phorone and other condensation products of acetone; but it contains, also, a body of the composition $C_9H_{14}O_3$, not combinable with phenyl hydrazine, to which the structure, $(CH_3)_2C{:}CH.C(OCO_2C_2H_5){:}CH_2$, is assigned. The author also gives a preliminary account of the action of benzoyl chloride on the phenyl hydrazone of acetone.

A. A. Noyes.

An Introductory Study of the Influence of the Substitution of Halogens in Acids upon the Rate and Limit of Esterification. By D. M. Lichty. *Am. Chem. J.*, 17, 27–31. — A preliminary note in which only a few results are communicated. The limit of etherification at 154° of equivalent quantities of ethyl alcohol and chloracetic acid was found to be 66.6 per cent., identical with that of alcohol and acetic acid. For dichlor-

acetic acid the value 70.7 per cent. was determined. The *rate* of etherification, however, is very much greater in both cases than with acetic acid. No reliable results could be obtained with bromacetic or with trichloracetic acid, and the etherification value for the monochloracetic acid diminished greatly on continued heating. The author attributes these phenomena to some unexplained secondary decompositions. The abstracter would suggest that these secondary reactions consist in the well-known conversion of the mono-halogen-acetic acids to glycolic acid and halogen acid, and of the trichloracetic acid to chloroform and carbonic acid by the water set free in the process of etherification. Either of these reactions would, of course, vitiate the etherification values.

A. A. NOYES.

On the Action of Sodium on the Esters of Aconitic and Citric Acids. Preliminary Notice. BY PAUL C. FREER. *Am. Chem. J.*, 17, 31–33. — The action does not consist merely in the replacement of hydrogen by sodium, but more complex sodium derivatives of a ketonic character are produced, probably by the elimination of sodium ethylate between two molecules of the ether. The products have been as yet but little investigated.

A. A. NOYES.

Diazobenzene Aniline Chloride. BY J. H. KASTLE AND B. C. KEISER. *Am. Chem. J.*, 17, 91–98. — By the action of less than the theoretical quantity of nitrosyl chloride on aniline hydrochloride in the presence of water, and subsequent precipitation with alcohol and ether, a white crystalline body is obtained which is believed by the authors to be a compound of diazobenzene chloride and aniline hydrochloride ($C_6H_5N_2Cl,C_6H_5NH_3Cl$). The presence of these two substances in it is clearly shown by its reactions. Boiling with water causes evolution of about two thirds of the nitrogen present, and phenol and aniline hydrochloride are found in solution. Reduction with stannous chloride yields phenyl hydrazine and aniline; treatment with potash, diazoamidobenzene. A substance identical in properties was also obtained by the addition of ether to a solution containing equivalent quantities of aniline hydrochloride and diazobenzene chloride. The authors do not, however, in either case offer any evidence that their substance is anything more than a mechanical mixture of the two chlorides. Their analyses are neither numerous nor accurate enough to establish definite proportions, and both chlorides are separately known to be precipitated from their aqueous solutions by ether.

A. A. NOYES.

On Imido-Ethers of Carbonic Acid. BY FELIX LENGFELD AND JULIUS STIEGLITZ. *Am. Chem. J.*, 17, 98–113. — The purpose of the investigation is to establish the constiution of the halogen acid addition-products of the halogen derivatives of imido-carbonic ethers and of carbodimides — for example, to determine which of the following reactions takes place:

$$C_6H_5.N{:}CCl.OC_2H_5 + HCl = C_6H_5.NHCl{:}CCl.OC_2H_5,$$

or

$$C_6H_5.N{:}CCl.OC_2H_5 + HCl = C_6H_5.NH.CCl_2.OC_2H_5;$$

$$C_6H_5N{:}C{:}NC_6H_5 + HCl = C_6H_5.NHCl{:}C{:}NC_6H_5,$$

or

$$C_6H_5N{:}C{:}NC_6H_5 + HCl = C_6H_5.NH.CCl{:}NC_6H_5.$$

The authors conclude that the second reaction is the correct one in each case. $C_6H_5N{:}CBr.OC_2H_5$ treated with gaseous hydrochloric acid yielded almost wholly $C_6H_5.NH.CO.Cl$ and C_2H_5Br. $C_6H_5N{:}CCl.OC_2H_5$ with gaseous hydrobromic acid yielded a considerable proportion of the same products, but a larger proportion of $C_6H_5.NH.CO.Br$ and C_2H_5Cl; from which it follows that the halogen of the acid does not combine directly with the ethyl group of the ether, but the acid forms an intermediate addition-product of the constitution, $C_6H_5.NH.CClBr.OC_2H_5$, which then decomposes into the mentioned products. For, if the halogen acid added itself to the nitrogen atom, forming a true salt, the principal decomposition products actually obtained could only be explained by assuming their constitution to be $C_6H_5NHCl{:}C{:}O$ and $C_6H_5.NHBr{:}C{:}O$, instead of $C_6H_5NH.CO.Cl$ and $C_6H_5.NH.CO.Br$, which assumption is not in accordance with the results of earlier investigations. This hypothetical addition-product could not be isolated, but the attempt was successful in the case of the *phenyl* ether, $C_6H_5O.CCl_2.NH.C_6H_5$, phenoxyformphenylamidodichloride (m. pt. 65°) being obtained by treating phenylanilidochlorformate in a freezing mixture with dry hydrochloric acid. The hydrochlorate of carbodiphenylimide was also shown to have the similar constitution, $C_6H_5N{:}CCl.NHC_6H_5$, by treating it with sodium ethylate, which gave as the product ethylisocarbanilide, $C_2H_5O.CNHC_6H_5{:}NC_6H_5$. Incidentally, the following new bodies were prepared and described: Bromformanilide, $C_6H_5NHCOBr$ (m. pt. 67°), prepared by passing dry hydrobromic acid over phenyl isocyanate. Phenylimidocarbonyl bromide, $C_6H_5N{:}CBr_2$ (b. pt. 127° at 20 mm.), by the addition of one molecule of bromine to phenyl isocyanide in chloroform solution at — 10°. Ethylanilidobromformate, $C_6H_5N{:}CBr.OC_2H_5$ (an oil decomposing into phenyl isocyanate and ethyl bromide when heated), by the action of sodium ethylate on phenylimidocarbonyl bromide. Phenylanilidochloroformate (m. pt. 41°) from phenylimidocarbonyl chloride and sodium phenolate. Carbodiphenylimide dichloride, $(C_6H_5NH)_2CCl_2$ (?), prismatic crystals decomposing at 130° and soluble in hot chloroform, was prepared by passing hydrochloric acid into a benzene solution of carbodiphenylimide until the precipitate first formed had redissolved.

A. A. Noyes.

On Some Bromine Derivatives of Paraisobutyl Phenol. By F. B. Dains and I. R. Rothrock. *Am. Chem. J*, **17**, 113–114. — Monobromparaisobutylphenol (m. pt. 50°) was prepared by the addition of one molecule of bromine to the sodium salt of the phenol under carbon bisulphide or to the phenol itself in aqueous solution. The benzoyl ether of this bromine derivative (m. pt. 78.5°) was prepared from it. By the addition of two molecules of bromine, or of a larger amount, a dibrom substitution product melting at 78° was also obtained.

A. A. Noyes.

On the Action of Acid Chlorides on the Methyl Ether of Paraisobutyl Phenol. By F. B. Dains. *Am. Chem. J.*, **17**, 114–116. — The work of the author is an extension of that of Gattermann (*Ber.*, **22**, 1129; **23**, 1199), who has shown that phenol ethers react with acid chlorides in the presence of aluminum chloride with formation of substituted ketones. To one part of *p*-isobutylphenol methyl ether and one of acetyl chloride dissolved in ligroin two parts of aluminum chloride are gradually added, and the mixture is then heated on a water bath. The solvent is poured off, the black residue washed

with water, the oil taken up in ether and distilled. The product consists of methoxyisobutyl acetophenone, $C_6H_3\,OCH_3(1)\,C_4H_9(4)\,COCH_3$ (2?) (b. pt. 262°–265°). Its ketoxime melted at 113°–114°. Methoxyisobutyl benzophenone (b. pt. above 315°) was prepared in a similar manner by means of benzoyl chloride.

A. A. NOYES.

The Action of Ammonia upon Dextrose. BY W. E. STONE. *Am. Chem. J.*, 17, 191–196. — A crystalline compound of dextrose with ammonia of the composition, $C_6H_{12}O_6NH_3$, was obtained by suspending dextrose in absolute alcohol saturated with ammonia, shaking frequently for ten days, decanting the solution and allowing it to stand for ten days or more, till crystallization had taken place. The product is a white solid of sweet taste, readily soluble in water with an alkaline reaction, insoluble in cold alcohol and ether. Melting point 122°–123°. Specific rotation $(\alpha)_D$: 22°–22.7°. Unlike dextrose, it does not have the property of birotation. It reduces Fehling's solution, undergoes fermentation, and reacts with phenyl hydrazine much less readily than dextrose. The same compound had been previously obtained in a similar manner by de Bruyn and Franchimont (*Rec. trav. chim.*, 12, 286), but it was not fully described by them.

A. A. NOYES.

On the Behavior of Allylmalonic, Allylacetic, and Ethylidenepropionic Acids when Boiled with Caustic Soda Solutions. BY JOHN G. SPENZER. *J. Am. Chem. Soc.*, 17, 1–33. — It having been observed by Fittig, v. Baeyer, and others that $\beta\gamma$ unsaturated acids when heated with a large excess of caustic soda are transformed into $\alpha\beta$ unsaturated acids, the author tries the action of the same reagent upon $\gamma\delta$ acids, namely, on allylmalonic and on allylacetic acids. In neither case does a transformation take place. Ethylidenepropionic acid on boiling with a large excess of caustic soda solution is transformed into propylideneacetic acid (m. pt. 7½°) to the extent of 60 per cent. The barium salt crystallizes in efflorescent needles, readily soluble in water and alcohol. The calcium salt, $(C_5H_7O_2)_2\,Ca + 4\,H_2O$, crystallizes in long, flat, glistening prisms, readily soluble in water. *a* β-dibromvalerianic acid, formed by the action of a carbon bisulphide solution of bromine upon a similar solution of the acid, crystallizes in broad leaves, which melt at 56°. It is readily soluble in carbon disulphide, benzene, and petroleum ether. β-bromvalerianic acid, prepared by the addition of hydrobromic acid to propylideneacetic acid, is a sandy, white crystalline body, melting at 59°–60°; readily soluble in ether, chloroform, carbon disulphide; less easily in benzene and petroleum ether; and almost insoluble in water at 0°. Crystallographic measurements are also given. When the mixture resulting from the action of caustic soda solution upon ethylidenepropionic acid is made acid and distilled with steam, ethylidenepropionic acid and propylideneacetic acid are driven over, while 36 per cent. of another acid, β-oxyvalerianic, remains in the retort. This on purification by dissolving in ether gave a colorless syrup. The acid is readily soluble in cold water, ether, benzene, and chloroform; insoluble in carbon disulphide and petroleum ether. The calcium, barium, and silver salts of the acid are described. On boiling β-oxyvalerianic acid with caustic soda, 56.6 per cent. unaltered oxyacid, 21.26 per cent. of ethylidenepropionic acid,

and 14.64 per cent. of propylideneacetic acid, were obtained, with a loss of 6.5 per cent. The distillation of β-oxyvalerianic acid yielded as the principal product propylideneacetic acid, with a small quantity of ethylidenepropionic acid. A table is given at the close of the article showing the various characteristics of allylacetic, ethylidenepropionic, and propylideneacetic acids.

T. EVANS.

β-Bromvalerianic Acid. BY JOHN G. SPENZER. *Am. J. Sci.*, 49, 110–111. — See the preceding abstract.

A. A. NOYES.

TECHNICAL CHEMISTRY.

Improvement in the Manufacture of Acetone. BY E. R. SQUIBB. *J. Am. Chem. Soc.*, 17, 187–201; *Squibb's Ephemeris*, 4, 1653–1665. — This is an account of an experimental trial of a continuous process for producing acetone directly from acetic acid. After much preliminary experimenting with a horizontal iron tube fixed in a very ingenious but simple furnace, the author decided that with a stationary tube "the physical and mechanical conditions of heating" were not conducive to equality of temperature; therefore he devised a rotary still, which yielded good results: "A wrought iron pipe 36 cm. long by 12.7 cm. diameter, contracted at the ends to central hollow journals of 2 cm. external diameter and 1.2 cm. bore, was supported free to revolve in the center of an 18 cm. drain tile furnace, and joined at one end with the vapor supply and at the other with the condenser, by air-tight glands or 'stuffing boxes.'" Charging and discharging openings, closing air-tight, were provided at the ends. The still was revolved by a pulley on the hollow journal, the speed of rotation being three to six revolutions per minute, the power being supplied by a water motor. Through the journals passed short pipes for vapor supply at one end and for the escape of the products at the other. A filter of wire cloth filled with glass wool prevented the outlet pipe from being choked with dust. Along the inside of the still, at equal distances, longitudinal shelves of sheet iron were fastened, to carry over and thoroughly mix the charge. The furnace consisted of a section of common drain tile placed horizontally. In the lower side six holes were made, through which the tubes of six Bunsen burners were introduced. On the upper side of the tile, holes were provided for the escape of the combustion gases, and the ends of the furnace were closed with tiles. This arrangement was found to give a very even heating of the charge, which filled about one third of the still. The acetic acid vapor was generated in a small flask by boiling, the supply being suitably regulated. The distillates from the still first passed through a flask kept at such a temperature that acetone would not condense, while water and undecomposed acetic acid were condensed. Then the vapors entered a long condenser, and the distillate was received in a flask cooled by ice. The uncondensed vapors next passed a wash bottle with water, and one with strong caustic soda solution, and could then be tested for carbon monoxide and marsh gas. The apparatus was connected with a Sprengel pump, by which a slightly diminished pressure was maintained. Distillations were made by passing the acetic acid vapor into the empty still while rotating, by passing the vapor through the still when nearly filled with granulated pumice stone,

by mixing precipitated barium carbonate with the pumice, and finally by putting barium carbonate alone in the still and passing the acid vapors through it. The yields of acetone were, respectively, 24.5 per cent., 24.3 per cent., 16 per cent., and 34 per cent. of the acid *decomposed.* In every case a greater or less amount of acid passed through the apparatus undecomposed. When carbonates were put in the still there was no formation of acetates till the temperature dropped to about 100° C. The author considers careful regulation of the heat within narrow limits as the most important detail of the process. Too high heat decomposes the acetone into marsh gas and carbon monoxide. The product is a dilute acetone fairly clean and of specific gravity 0.93–0.97. The distillate is a good solvent for many substances, and can be used for making chloroform. An investigation of the specific gravity of pure acetone when diluted with water was also made in this connection:

Per Cent. Acetone by Weight.	Specific Gravity at:		
	$\frac{4^\circ}{4^\circ}$ C.	$\frac{15^\circ}{15^\circ}$ C.	$\frac{25^\circ}{25^\circ}$ C.
20	0.9794	0.9755	0.9726
40	0.9527	0.9454	0.9397
50	0.9334	0.9247	0.9180
70	0.8877	0.8790	0.8709
80	0.8626	0.8536	0.8450
90	0.8371	0.8260	0.8168
100	0.8082	0.7966	0.7870

F. H. Thorp.

An Investigation of the Twitchell Method for the Determination of Rosin in Soap. By Thomas Evans and I. E. Beach. *Am. Chem. J.*, 17, 59–67. — This investigation was undertaken with the purpose of discovering and explaining the causes of the discrepancies in the results obtained in analyses by Twitchell's method. Both the gravimetric and volumetric methods were carried out under varying conditions. In the volumetric method Twitchell's directions were closely adhered to, but in the gravimetric work the recommendation of Lewkowitch concerning the repeated washing of the petroleum-ether extraction with dilute caustic potash was followed in order that complete saponification of the rosin might be assured. The samples analyzed were in most cases prepared by mixing known weights of rosin and fatty acids and then melting together on the water bath. It was found that the combining weight, 346, given by Twitchell for rosin, was not a fixed quantity, but varied in different samples of rosin used. The grade or color of the rosin proved not to be a sufficient basis on which to establish the combining weight. When the combining weight of a rosin was once known the volumetric method gave very good results. The gravimetric method was unsatisfactory, as losses of 10–15 per cent. occurred. This had been investigated by Lewkowitch, who could not account for the loss except on the theory that part of the rosin was decomposed by the action of the hydrochloric acid. The authors decided that the petroleum-ether extraction, from which all the saponifiable matter was supposed to be removed by the caustic potash, was the place to seek for this loss. Accordingly samples of this

petroleum-ether layer, after thorough washing with potash, were evaporated to dryness, and yielded gummy masses having an odor resembling turpentine. These amounted to 9.71 per cent. and 9.54 per cent., respectively, of the original rosin. The mass proved to be unsaponifiable with alcoholic potash. Experiments were then made by dissolving rosin directly in petroleum-ether, washing with caustic potash, and examining the petroleum-ether again. In each case gummy residues resembling that previously mentioned were obtained, amounting to 8.8 per cent., 9 per cent., and 9.1 per cent., respectively, of the original rosin. Apparently the action of the hydrochloric acid was not responsible for the formation of this unsaponifiable matter. Several grades of rosin were then examined for unsaponifiable matter, and their combining weights calculated on the basis of saponifiable rosin present were found to approach very nearly an average number of 316.

F. H. THORP.

The Asphalt Question. BY S. F. PECKHAM. *J. Am. Chem. Soc.*, 17, 55–63. — The author criticises severely several papers on asphalt by different chemists, but especially that by C. Richardson (*J. Anal. Appl. Chem.*, 6, 696; 7, 28). Errors resulting from the use of improper solvents are also shown in the work of several analysts.

F. H. THORP.

Alkali and Sulphurous Acid Processes Used in the Manufacture of Starch from Corn. BY HORACE E. HORTON. *J. Am. Chem. Soc.*, 17, 68–69. — The article consists of two very concise outlines of the processes, showing all their essential points.

F. H. THORP.

Some Practical Points in the Manufacture of Nitroglycerol. BY J. E. BLOMEN. *J. Am. Chem. Soc.*, 17, 263–277. — The questions here considered are: The best methods of stirring the mixture of acids and glycerol so as to avoid dangerous heating and secure economical working; the most convenient size of the charge; separators, their forms, size, and number; the treatment of the nitroglycerol in the washhouse; the size of the drowning tanks; methods of ascertaining the amount of nitroglycerol on hand at any time and the daily output of the works; methods of conveying the nitroglycerol from the storage tanks to the mixing house; the construction of the plant with reference to the use of compressed air or of gravitation for moving the nitroglycerine; the construction of the buildings and the safe distance between them; methods for controlling the quality of the materials used; disposal of "waste acids" and acid wash waters, and recovery of the acids.

F. H. THORP.

Methods for the Examination of Glycerol for Use in the Nitroglycerol Manufacture. BY G. E. BARTON. *J. Am. Chem. Soc.*, 17, 277–280. — The author gives the methods which he finds satisfactory after several years' experience in this work. He considers the following determinations essential: Carbonaceous residue and ash, sodium chloride, total acid equivalent, higher fatty acids, neutrality, specific gravity, and permanent specific gravity.

F. H. THORP.

The Use of Sulphurous Acid ($NaHSO_3$) in Manufacture of Glucose Syrup and Grape Sugar. By HORACE E. HORTON. *J. Am. Chem. Soc.*, 17, 281–286. — The author describes the preservative action of this acid on the color of the syrups, where it has great value, as well as in the matter of giving brilliancy to candy, the claim made by some candy makers that its use results in sticky candy being shown false. The addition of bisulphite in large quantity permits the boiling of candy at a much higher temperature than when none is used. There was no apparent effect on the activity of the yeast when this glucose was used in brewing, but the bisulphite was shown to accelerate the crystallization of grape sugar solutions, while also exerting a marked bleaching action.

F. H. THORP.

Stamp Sand in Cement Mortar. By EDGAR KIDWELL. *Eng. Mining J.*, 59, 173. — This article contains the tabulated results of a large number of tests of cement mortars made with standard quartz sand and with stamp sand taken directly from the dump of a stamp mill. The stamp sand was the result of crushing melaphyr, was very coarse, and contained some dirt. It was used in the mortars without washing or sifting. Five different grades of cement were used, viz.: Portland, Buffalo, Akron, Louisville, and Rosendale, and the results show conclusively the greater strength of mortars made from stamp sand.

F. H. THORP.

Why Rubber Tires Deteriorate. By J. CARTER BELL. *India Rubber World*, March 10, 1895. — The deterioration is in many cases due to the ingredients used in compounding the rubber, or to the temperature and other conditions during vulcanization. Iron oxides, cheap gum substitutes, especially those of an acid nature or which liberate acids during vulcanizing, oily matters, and excess of sulphur or of earthy fillers are all liable to cause deterioration. Vulcanization at too high a temperature or for too short a time also results in a poor product. Exposure to sunshine and oiling the surface of rubber articles are also claimed to be injurious.

F. H. THORP.

On Some Possible Sources of Error in the Hide-Powder Method of Tannin Determination. By H. R. PROCTOR. *The Leather Manufacturer*, 5, 3–4. — Professor Proctor in this short article presents a number of facts which should be carefully considered by chemists using this method in tannin determinations. While proposing no better method, he shows the weak points of the process and makes suggestions relative to further investigations in certain lines. Some of the items considered are: The mode of solution of the sample analyzed, the effect of temperature on the solubility of its various constituents, and the possible influence of acetic or other acids when used to assist in the solution; effects of oxidation during evaporation and drying, and a suggestion that this be done *in vacuo* or in neutral gases for exact data; variations in the amount of soluble matter in the hide-powder used and the effect of incipient decomposition of the hide-powder before use; the fact that hide-powder takes up other matters than tannins and the results of using a large excess of hide-powder; lastly, the influence of the fineness and other physical properties of the hide-powder.

F. H. THORP.

Relation between Color and Composition in the Tetrazo Group. By Howard S. Neiman. *Textile Colorist*, 17, 1. — The author has tabulated thirty-eight tetrazo dyes arranged according to their hues, from greenish yellow, through orange and scarlet to bluish red; then from tables of their compositions he indicates the influence exerted by different groups in modifying the hue of the dye.

J. W. Smith.

Sanitary Chemistry.

The Sand Filtration of Water. By George W. Fuller. *J. Am. Public Health Assoc.*, 1, 64–71. — The author gives a clear and concise statement of the chemical and biological principles which govern the purification of water during its passage through sand of a suitable character as to size, depth, etc. These principles are illustrated by figures obtained during the past seven years at the Lawrence Experiment Station in the filtration of Merrimack River water. These show that 98.5 per cent. of the bacteria were removed by the experimental filters. There is also given the results of the first year's work of the large filter bed, which filters some 5,000,000 gallons daily, and removes 98.3 to 99 per cent. of the bacteria. The supply of this filtered water has reduced the death-rate of the city of Lawrence 60 per cent.

E. H. Richards.

Report of the Committee on the Pollution of Water Supplies. By Charles Smart. *J. Am. Public Health Assoc.*, 1, 72–82. — The paper deals mainly with work done abroad, but refers briefly to various experiments in this country, and recommends a coöperative investigation of the various groups of water bacteria.

E. H. Richards.

Pure Water versus Purified Water for Public Water Supplies. By Daniel W. Mead. *J. Am. Public Health Assoc.*, 1, 49–52. — The author pleads for the recognition by cities and towns of the value of expert advice on these matters.

E. H. Richards.

The Well Waters of Our Farm Homesteads. By Frank T. Shutt. *J. Am. Public Health Assoc.*, 1, 44–48. This paper would serve admirably as a tract to be circulated all over the country. The causes of pollution and the dangers of using these wells, with some plain remedies for existing conditions, are very forcibly stated.

E. H. Richards.

The Cart Before the Horse. By Benjamin Lee. *J. Am. Public Health Assoc.*, 1, 34–37. The author shows the folly of introducing an abundant water supply without at the same time providing a means for the quick removal of the increased quantity of polluted water.

E. H. Richards.

Water Purification. By Rudolph Hering. *J. Franklin Institute*, 139, 139–145. — This is a clear and concise statement of the present state of knowledge on the subject, and should be read by all engineers who have anything to do with water supplies. It is free from technical terms, and yet maintains a scientific character throughout. The paper gives good classification of water fit for domestic use, and states various means used to improve

the quality of water which is not up to standard. The methods are discussed from a broad standpoint, and many facts of value are brought together in a readable form. For instance, the author says: "With respect to all these rapid filters we may say that what is gained in rapidity is lost in efficiency; . . . it is true that the character of the water may be greatly improved, . . . but we cannot place entire confidence in rapid filtration for always turning out pure water."

E. H. RICHARDS.

Improved Methods of Water Analysis. BY IRVING A. BACHMAN. *J. Am. Chem. Soc.*, 17, 296–303. — The author is engaged in an investigation of the differences between malaria-producing waters and good waters, and in this paper gives his experience in searching for the best methods of analysis. There is described, with figures, a new arrangement of apparatus for distillation and one for concentration. The results of a modification of the Wanklyn and of the Kjeldahl processes are given, and a good word is spoken for the Frankland process. The author seems to cling to the old notion that albuminoid ammonia is the important determination to make, and that its exact quantitative estimation is worth a great deal of trouble. He is apparently not familiar with the discussion of this subject in the Reports of the Massachusetts State Board of Health, nor with the manner of using the Wanklyn process practiced in its laboratory.

E. H. RICHARDS.

The Atmosphere of a Large Manufacturing City. BY C. F. MABERY. *J. Am. Chem. Soc.*, 17, 105–122. — The effect of large manufacturing industries concentrated in or near a city on the air of the place has been little studied in this country. A noteworthy example of such a study is given in the paper above noted. The air about Cleveland was examined, a city where more than a million tons of coal, largely bituminous, are burned in a year. The following table is selected from those given, in order to show the extent to which the soot, or unconsumed carbon, outweighs all the other impurities, as well as to indicate the careful and painstaking work of the author.

	Weight soot per liter.	Weight H_2SO_4 per liter.	Weight NH_3 per liter.
1	0.0875 gram.	0.0152 gram.	0.00007 gram.
2	0.0452 gram.	0.0063 gram.	0.00001 gram.
3	0.1113 gram.	0 0212 gram.	0.00012 gram.
4	0.0418 gram.	0.0139 gram.	0.000003 gram.
5	.....	0.0070 gram.	.....

Locality.	Weather.	Wind.	Volume of air at 0° and 76 cm. liters.	Weight CO_2.	Weight soot in 1,000,000 cubic meters.
1	Clear.	N.	94.0	0 0034 gram.	9,875 grms.
2	Clear.	S. W.	70.2	0.0017 gram.	6,609 grms.
3	Clear.	N. W.	88.2	0.0051 gram.	15,773 grms.
5	Clear.	S. W.	92.5	0.0042 gram.	12,386 grms.
5	Clear.	N. W.	88.7	0 0005 gram.	1,538 grms.
6	Cloudy.	W.	89.3	0.0054 gram.	16,491 grms.
6	Clear.	W.	91.3	0.0027 gram.	8,065 grms.
8	Clear.	N. W.	94.3	0.0053 gram.	15,330 grms.
8	Clear.	N. W.	77.9	0 0140 gram.	39,906 grms.

He concludes the paper with the following pertinent remark: "From the results of this examination it is evident that a city atmosphere contaminated by the universal consumption of bituminous coal where no efforts are made to prevent the escape of soot soon reaches a stage in which it is destructive to property and not conducive to health. In this respect the atmosphere of Cleveland is, doubtless, no worse than that of other cities, and perhaps in a better condition than some that use the same fuel. Under the usual conditions of life in cities sanitary regulations require careful attention and constant supervision."

E. H. RICHARDS.

The Synthetic Food of the Future. BY HARVEY W. WILEY. *J. Am. Chem. Soc.*, 17, 155–178. — The author sees no reason whatever for supposing that the synthetic production of food can ever become of much economic importance.

E. H. RICHARDS

Coloring Matter in the California Red Wines. BY W. D. BIGELOW. *J. Am. Chem. Soc.*, 17, 213–218. — The author has compared the behavior of California wines towards the reagents usually employed in testing the coloring matter of European wines, and finds that the former are more uniform in character and that they do not show any of the color tests peculiar to adulterated wines.

E. H. RICHARDS.

The Phosphomolybdic Acid Test as Applied to Lard Analysis. BY GEORGE F. TENNILLE. *J. Am. Chem. Soc.*, 17, 33–41. — P. Welmans (*Pharm. Zeit.*, 36, 798) dissolves 1 gram of fat in 5 cc. chloroform, adds 2 cc. phosphomolybdic acid solution, and shakes. The presence of cottonseed or other vegetable oil colors the upper layer green. The addition of alkali changes the green to blue. The author has made a critical examination of this test, and he finds that the green and blue coloration is only conclusive in the case of crude cottonseed oil. The more perfectly it is refined the less the coloration; therefore it would seem that another instance is added to the already long list of coloration tests for impurities in oils and fats which have not stood the test of wider application. These products are of such a complex nature and are liable to so many changes in character as the processes of manufacture change that it is not safe to rely on any one test. This is clearly shown in the paper in question. The author discusses the iodine absorption figure and describes the different methods of rendering lard. He also gives some comparative figures as to the behavior of the lards thus obtained, and gives results on lard from the different portions of the body, from which it would appear that the term "a lard" must be used, since each part of the animal seems to furnish fat of a different character.

E. H. RICHARDS.

Quick Estimation of Starch. BY P. L. HIBBARD. *J. Am. Chem. Soc.*, 17, 64–68. — The author uses coarsely pulverized dry malt, which is covered with water containing from 15 to 20 per cent. of alcohol. After a few hours maceration the infusion is filtered off. The alcohol is used as an antiseptic, and a solution containing 20 per cent. will keep at least two weeks without destroying the diastatic power of the malt extract. The finely pulverized

sample, which may contain half a gram or more of starch, is digested at a boiling temperature with 50 cc. of water and one or two of the malt extract. After boiling a minute the mixture is cooled to 50° or 60° C., and two or three cubic cc. of malt are added. Then it is heated slowly from ten to fifteen minutes until boiling, partially cooled, and tested by iodine. If the starch is not all converted, the treatment must be repeated. Fine muslin or linen is used for the filter. An aliquot part of the filtrate containing .2 or .3 of a gram of starch is treated in a 100 cc. flask, with 5 cc. HCl containing 30 per cent. acid gas. Make up with soda to about 60 cc. Complete conversion occurs after boiling about thirty minutes. If the water bath is used, longer time is required and a condenser may be necessary. The solution is nearly neutralized by sodium hydrate, and the dextrose determined by Fehling's solution. — The method is simple, rapid, and fairly accurate. The determination of starch may be easily finished in less than two hours. It is especially applicable to foods and residues from starch manufacture. The particular points claimed are prevention of insoluble clots by first addition of malt, that is, before heating. The rapid heating prevents lactic acid fermentation, which may occur in the use of the older methods. The short time of boiling gives rise to a minimum of bodies other than starch which might go into solution and form reducing sugars.

E. H. RICHARDS.

AGRICULTURAL CHEMISTRY.

The Action of Organic and Mineral Acids upon Soils. BY HARRY SNYDER. *J. Am. Chem. Soc.*, **17**, 148–151. — The soil examined was from one of the plots at the Minnesota Experiment Station, and the examination was made in order to decide upon the best method of determining the amount of mineral matter likely to be rendered soluble in the course of plant growth, and to compare the effect of hydrochloric acid with that of the organic acids. The following table shows the amount in per cent. of the various substances dissolved, and indicates that hydrochloric acid of the given strength may be safely used.

	Hydrochloric acid, 1.115 sp. gr.	Ten Per Cent. Solution of			
		Citric acid.	Oxalic acid.	Tartaric acid.	Organic acid mixture.
Insoluble residue	84.08	87.90	85.07	87.67	85.93
Potash	0.30	0.12	0.18	0.06	0.10
Soda	0.25	0.17	0.19	0.05	0.12
Lime	0.51	0.50	0.23	0.41	0.45
Magnesia	0.26	0.27	0.21	0.32	0.33
Iron oxide	2.56	1.59	1.14	1.62	2.23
Alumina	4.24	1.45	3.96	1.77	2.99
Phosphoric anhydride	0.23	0.26	0.14	0.11	0.26
Sulphuric anhydride	0.08	0.10	0.05	0.06	0.05

E. H. RICHARDS.

VEGETABLE CHEMISTRY.

The Carbohydrates of the Gum of Acacia Decurrens. BY W. E. STONE. *Am. Chem. J.*, **17**, 196–199. — This gum is found to be essentially identical in composition with gum arabic, peach and cherry gums. Like these, it yields 25.4 per cent. of furfurol when distilled with hydrochloric acid (sp. gr. 1.06), 11.4 per cent. mucic acid on heating with nitric acid (sp. gr. 1.15), and arabinose, and probably also galactose, on heating with very dilute sulphuric acid.

A. A. NOYES.

METALLURGICAL CHEMISTRY AND ASSAYING.

The Use of New and Old Cupels. BY H. G. TORREY. *Eng. Mining J.*, **59**, 219. BY W. M. COURTIS. *Ibid.*, **59**, 243. — Cupels are commonly air-dried before using, in order to prevent the bullion from spurting while it is being cupelled. At the United States Assay Office in New York City three months were always allowed for this until Mr. Torrey's tests showed that this was unnecessary, as out of one thousand cupels less than a week old and one thousand one year old the same number, viz., 1 per cent., spurted. W. M. Courtis attributes the spurting to the presence of organic matter rather than to moisture, and says that no spurting will occur if a cupel, before charging, is first heated in the muffle with a closed door and the door then opened to burn off any organic matter. The experience of the Assay Department of the Massachusetts Institute of Technology is the same as that of Mr. Courtis.

H. O. HOFMAN.

A Possible Explanation of Kernel Roasting. BY H. M. HOWE. *Eng. Mining J.*, **59**, 104–105, 267. — If copper-bearing pyritic ore, free from gangue and in lump form, is roasted slowly in heaps or stalls, the bulk of the copper of a roasted lump will be found to have been concentrated in the center as a kernel of sulphide, and this surrounded by a rind of ferric oxide containing only very little copper. This concentration of the copper distributed pretty uniformly through the raw lump has been attributed by Plattner to the great fusibility of copper sulphide, and his explanation is generally accepted to-day; but nobody has so far given a reason why plastic copper sulphide, which was at the bottom of a lump, should travel upward or that on the side inward. Mr. Howe accounts for it by capillarity, which, he says, causes the plastic copper sulphide to adhere to the solid, undecomposed sulphide center within and to retreat from the porous ferric oxide without. He shows in the second communication that the explanations offered by H. G. Z. (*ibid.*, 147) and G. McRoss (*ibid.*, 195) cannot be accepted. The former suggests an outward travel of iron sulphide. This would not, however, effect an inward travel of copper sulphide. The latter draws attention to the magnetic property of the kernel, and looks for the explanation in magnetic attraction. Mr. Howe gives some experiments of his in magnetic concentration of lump-roasted ore when the iron oxide rind proved to be more attracted by the magnet than the rind; he further attributes the magnetic property of the kernel to the iron sulphide and not to the copper sulphide, and shows that the kernel is attracted by the magnet in the same way as are, *e.g.*, iron filings, which are magnetizable but not themselves magnets; hence magnetism cannot be the cause of the copper's traveling toward the center.

H. O. HOFMAN.

Amalgamation and the Russell Process at the Blue Bird Mill. By T. H. Russell. *Eng. Mining J.*, **59**, 99. — Mr. Russell, referring to a paper by Mr. C. A. Hoyt (*ibid.*, **55**, 8), where the extraction of silver from Blue Bird ore by amalgamation is shown to have varied from 58.5 per cent. to 80 per cent., while that by the Russell process averaged 84.1 per cent., says that these figures refer to the time when it was customary to wet down the roasted ore shortly after its discharge from the furnace, which changed the form of the silver in the ore so as to make it more difficult of solution in sodium hyposulphite than when the ore was wetted down cold. In the latter case the silver extracted by amalgamation was 90 per cent.

H. O. Hofman.

Inferences from Andrews' Late Researches on the Corrosion of Iron. By H. M. Howe. *Eng. Mining J.*, **59**, 99. — Andrews has shown that steel in its normal condition is not so quickly attacked by sea water as steel which has been distorted cold, proving that the former is electropositive to the latter. The result is that if normal ("unstrained") steel is in contact with distorted ("strained") steel the total amount of corrosion will be increased, owing to their difference in potential. Strained steel is mechanically weaker than unstrained. Mr. Andrews' investigations show that it also rusts quicker; hence punched boiler plate will not last as long as one that has been drilled, if the strain is not removed by annealing or by reaming out the punched ring.

H. O. Hofman.

Cyanogen Bromide and Potassium Cyanide for Dissolving. By E. A. Schneider. *Eng. Mining J.*, **59**, 266. By H. L. Sulman. *Ibid.*, 291. — The patentee of this new solvent for gold, Mr. H. L. Sulman, says it dissolves gold from three hundred to six hundred times as fast as potassium cyanide does. He claims that gold from sulphides was completely extracted in twenty hours, when it took a week to do the work with potassium cyanide alone. The reaction that takes place is expressed by the equation:

$$3KCy + BrCy + Au_2 = 2KAuCy_2 + KBr,$$

and the quick solution is attributed to the absence of the potassium hydroxide formed when potassium cyanide alone is used. In preparing the solvent the cyanogen bromide is added in the proportion required by the equation to a solution of potassium cyanide containing from 0.1 to 0.5 per cent. of the salt. Cyanogen bromide is prepared by the action of bromine on any suitable metallic cyanide. Mr. Schneider found independently that the addition of cyanogen bromide to potassium cyanide hastens the solution of gold, but he also found that the addition of bromine to a potassium cyanide solution hastens its decomposition, and therefore does not believe it can be made a commercial success.

H. O. Hofman.

Melting and Refining of Gold Bullion. By H. Van F. Furman. *School Mines Quart.*, **16**, 25. — This is a brief description of the gold-bearing material a refiner has to deal with, of the effect of impurities on the physical properties of gold, and of the operations of melting and refining impure gold and of sampling the bar into which the refined gold is cast.

H. O. Hofman.

Theory of Electro-metallurgy. By F. B. Crocker. *School Mines Quart.*, 16, 97–123. — The author gives a short, concise review of the chemical and physical laws of electro-metallurgy, which he defines as "that branch of science which relates to the electric reduction or treatment of metals." The reprint of the article in pamphlet form will be welcomed by metallurgists.

H. O. Hofman.

Improvements in Matte Smelting. By H. Lang. *Mining Science and Press*, 70, 20–21. — Mr. Lang distinguishes two processes, the "Austin Process" and the "Gradual Reduction Process." In the former occurs a quick combustion of part of the sulphur at the region of the tuyeres, followed by fusion, the combustion being assisted by superheated blast. Charges containing from 10 to 20 per cent. sulphur have been successfully smelted, using only from 4 to 5 per cent. coke. The disadvantage of this process is that low grade matte results, as hardly any roasting of the charge takes place in the furnace. In the "General Reduction Process" advocated by Mr. Lang the charge is roasted to a considerable extent during its passage through the shaft furnace previous to fusion, with the result that a rich matte is produced. Thus Mr. Lang has obtained a concentration of twenty into one, with ore containing 20 per cent. sulphur, using 6¼ per cent. Connellsville coke and having only cold blast. He condemns water-jackets and advocates brick walls for his process, as the temperature is not high enough to warrant the loss of heat caused by jackets; he also prefers vertical side walls to a bosh, as his aim is to allow free oxygen to ascend in the shaft and roast the ore before it arrives at the zone of fusion. The losses in precious metal by pyritic smelting are judged not to be excessive, as a pyritic-smelting plant in Colorado competes successfully with silver-lead smelting works for the same class of ores.

H. O. Hofman.

The Resistance to Corrosion of Some Light Aluminum Alloys. By J. W. Richards. *J. Franklin Institute*, 1895, 69; *Iron Age*, 55, 64. — The researches described in the paper refer to the behavior of alloys with 3 per cent. copper, 3 per cent. German silver, 3 per cent. nickel, and 2 per cent. titanium (all of a specific gravity less than 3), with dilute caustic potash (3 per cent. solution, cold), dilute hydrochloric acid (3 per cent. solution, cold), concentrated nitric acid (cold), strong acetic acid (60° C.), a strong solution of common salt (65° C.), and a solution of carbonic acid (25° C.). From the numerical results given in three tables the following conclusions are drawn: Alkali acts less on the pure metal than on alloys; if more strength is wanted than the aluminum can furnish, the copper alloy, as being the least attacked, should be chosen. Hydrochloric acid acts least on the titanium alloy, nitric acid on the pure metal. If strength is wanted in connection with acetic acid the titanium alloy should be chosen. A salt solution has but little effect on the pure metal. Of the alloys the German silver one is the most resistant. A solution of carbonic acid shows the least corrosion with titanium and copper alloys.

H. O. Hofman.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

Preliminary Notice of the Plymouth Meteorite. BY HENRY A. WARD. *Am. J. Sci.*, **49**, 53–55. — This meteorite was found in 1883 five miles southwest of Plymouth, Marshall County, Indiana. The brief description is accompanied by the following analysis, made by Mr. J. M. Davison:

Fe, 88.67; Ni, 8.55; Co, 0.66; Cu, 0.24; P, 1.25; Graphite, 0.11; S, 0.07. Total, 99.55.

W. O. CROSBY.

Constituents of the Cañon Diablo Meteorite. BY ORVILLE A. DERBY. *Am. J. Sci.*, **49**, 101–110. — The specimen analyzed, weighing nearly 200 grams, was an original fragment or part of the Arizona meteorite, in which diamonds were reported by A. E. Foote. After removing the crust of rust by soaking in strong acid and scraping, the meteorite was treated with cold dilute (1 to 10) HCl for fourteen weeks, a considerable irregular, jagged mass remaining undissolved at the end of that time. This undissolved residue was found to consist of massive schreibersite ($(FeNi)_3P$), rhabdite (another phosphide of iron and nickel, a variety of schreibersite), cohenite ($(Fe,Ni,Co)_3C$), taenite (nickeliferous iron containing about 25 per cent. of nickel), and a black coal-like dust. An analysis of the solution gave: Fe, 91.264; Ni and Co, 8.252; P, 0.440; Cu, 0.044. This agrees fairly well with the composition of kamacite ($Fe_{14}Ni$). The insoluble taenite gave: Schreibersite, 1.65; Fe, 66.46; Ni, 30.28; Co, 0.68; Cu, 0.32; P, 0.30 = 99.69. Two analyses of the cohenite gave:

	Fe	Ni and Co.	P.	C.	Total.
I.	92.88	1.33	0.48	5.33	100.02
II.	91.67	2.43	0.09	6.07	100 26

The phosphorus in these results indicates that the solvent had attacked the schreibersite. Schreibersite and rhabdite are regarded as essentially identical, differing only in the habit of crystallization; but a third variety of iron and nickel phosphide detected in this meteorite is shown to differ in composition from the others. It is noted that the most reliable previous analyses of meteoric phosphides show very variable relative proportions of iron and nickel and cobalt even in the same meteoric mass; and as regards phosphorus, they may be divided into two groups, a larger one with about 15 to 16 per cent., and a smaller one with about 12 to 13 per cent. The schreibersite of the Cañon Diablo meteorite belongs chiefly in the latter group. As in the course of this investigation, which was mainly undertaken for the purpose of verifying the reported existence of the diamond in the Cañon Diablo meteorite, nothing resembling that substance or any other form of free carbon could be detected, it was suspected that possibly the polishing effect produced by the residue of the dissolved mass and attributed to the presence of diamond dust might be due to schreibersite, which appears to be hard enough to scratch topaz and depolish sapphire.

W. O. CROSBY.

The Basic Massive Rocks of the Lake Superior Region. BY W. S. BAYLEY. *J. Geol.*, **3**, 1–20. — This is a continuation from the preceding volume of a systematic petrographic description of the rocks indicated in the title, and a few only of the component minerals were submitted to analysis. A remarkably fresh and transparent hypersthene from the granulitic gabbro yielded:

SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO_2.	CaO.	MgO.	$H_2O(105°)$.	Total.
48.44	7.91	0.33	20.88	0.92	1.44	19.35	0.08	97.35

Two of the hypersthenic rocks were also analyzed: I. Granulitic hypersthene-gabbro, very rich in hypersthene and biotite and poor in feldspar. II. Granulitic diallage-hypersthene-gabbro; diallage much more abundant than hypersthene, and no mica.

	SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	NiO.	MnO.	CaO.
I.	46.96	0.62	14.13	0.76	14.95	0.06	0.93	2 32
II.	49.56	0.48	17.81	2.76	9.48	....	0.06	9.70

	MgO.	K_2O.	Na_2O.	H_2O.	P_2O_5.	Total.	Sp. Gr.
I.	15.97	1.68	0.35	1.33	0.03	100.09	3.193
II.	5.93	....	2.87	0.50	0.67	99.82	2.967

W. O. Crosby.

A Petrographical Sketch of Ægina and Methana. By Henry S. Washington. *J. Geol.*, **3**, 138–168. — This is the third and concluding part of an elaborate study of the igneous rocks of two Grecian islands, and includes the chemical discussion. Complete analyses (sixteen in number) are given in tabular form for all the prominent varieties of the region. These show a regular gradation in silica from the most basic andesite (54.53 per cent.) to the most acid dacite (68.91 per cent.) As usual in the case of volcanoes very near the sea, chlorine was found in every lava which was tested for it. The interesting fact is brought out that segregations in these rocks are always more basic than the rock which contains them; they are also notably richer in lime and magnesia and poorer in alkalies, and these differences are shown to accord well with the modern theory of magmatic differentiation.

W. O. Crosby.

The Magnesian Series of the Northwestern States. By C. W. Hall and F. W. Sardeson. *Bull. Geol. Soc. Am.*, **6**, 167–198. — The magnesian series includes five formations — three dolomites and dolomitic shales and two silicious sandstones. Enumerated in ascending order, they are: 1. St. Lawrence dolomites and shales; 2. Jordan sandstone; 3. Oneonta dolomite; 4. New Richmond sandstone; 5. Shakopee dolomite. Following the detailed description of these strata is a discussion of the genesis of the series. The sandstones and shales present, in this respect, no problems of special interest, and the chief attention is given to the dolomites. The history of opinion concerning the origin of dolomites is briefly summarized. Analyses are quoted to show that while there is approximately four times as much magnesium salts in modern sea water as there is calcium salts, recent geological calcareous sediments of marine origin contain on the average only 2.45 (extremes 1.04 and 5.00) per cent. of $MgCO_3$ to 92.51 per cent. of $CaCO_3$. Believing that similar conditions must have obtained in Paleozoic times, the conclusion is reached that the dolomitic strata of the magnesian series of the Northwest were first deposited as slightly magnesian limestones, and their conversion to nearly pure dolomites is due to a subsequent transformation. The question is then raised as to whether this change from limestone to dolomite is due to the introduction of more and more $MgCO_3$ subsequent to the formation of the rock, or to the gradual removal of $CaCO_3$ from the rock by differential erosion. The difficulty of finding an adequate supply of $MgCO_3$ for the first process, and the fact that analyses of spring waters show that the proportion of $CaCO_3$ dissolved by percolating waters far exceeds that of $MgCO_3$, lead the authors to accept the differential erosion theory. The

beginning of the change from limestone to dolomite dates from the elevation of the strata above the sea or the general drainage level of the continent; and its practical completion has involved not only an enormous loss of $CaCO_3$, but a corresponding reduction of volume, one thousand feet, it is estimated, of the original limestone being required to form one hundred feet of dolomite.

W. O. CROSBY.

Crystalline Limestones and Associated Rocks of the Northwestern Adirondack Region. BY C. H. SMYTH, JR. *Bull. Geol. Soc. Am.*, **6**, 263–284. — The principal rock associated with the crystalline or sparry limestones of this region is gabbro, of three different varieties. The third variety largely prevails, and is of somewhat unusual character. It varies, as the result of original magmatic differentiation, from a nearly normal basic gabbro (I) to a highly acid type consisting largely of microperthite (II), and the following analyses of these extreme phases are given:

	SiO_2.	Al_2O_3.	FeO.	MgO.	CaO.	K_2O.	Na_2O.	H_2O.	Total.
I.	57.00	16.01	10.30	1.62	6.20	3.53	4.35	0.15	99.16
II.	65.65	16.84	4.01	0.13	2.47	5.04	5.27	0.30	99.71

W. O. CROSBY.

Honeycombed Limestones in Lake Huron. BY ROBERT BELL. *Bull. Geol. Soc. Am.*, **6**, 297–304. — The limestones in the bottom of a certain portion of Lake Huron, namely, that around Grand Manitoulin Island, the Indian Peninsula, and in Big Gap, which lies between them, are undergoing a peculiar kind of erosion, which may be called honeycombing and pitting. This curious and possibly unique form of erosion affects various kinds of limestone and dolomite. The unaltered varieties have been completely riddled with cavities varying from very small holes up to 3 inches or more in diameter, the forms of the cavities varying from globular to cylindrical or cigar-shaped. In altered or crystalline varieties the pits are mostly larger and shallower. The rocks affected by the honeycombing are so varied as to indicate that the erosive process is not due to anything unusual in the composition of the rocks, but to some outside cause. The pitted character of the eroded surface means, however, that the rock varies in susceptibility to erosion at closely adjacent points, and this is correlated with a faintly marked concretionary structure. In searching for the agent of erosion, boring mollusks, sponges, and algæ, and the wearing action of pebbles are duly considered and rejected, and the conclusion is reached that the action is purely chemical and due to acid water. In other words, the pitting is due to the differential solubility of the limestone in the water of the lake. Although the water of this part of Lake Huron has not been analyzed, it appears to contain a notable proportion of free sulphuric acid. It reddens litmus, and its corroding action on tin vessels is a source of annoyance to those who use the water for domestic purposes. The water of this portion of the lake is distinctly harder than elsewhere, probably owing to the presence of sulphate of lime, which has resulted from the reaction of ferrous sulphate with calcium carbonate. The source of the sulphuric acid is found in the oxidation of sulphides — pyrite, pyrrhotite, etc. — contained in exceptional abundance in the Huronian rocks north of Lake Huron.

W. O. CROSBY.

Disintegration of the Granitic Rocks of the District of Columbia. By GEORGE P. MERRILL. *Bull. Geol. Soc. Am.*, **6**, 321–332. — From one of the numerous sections, where the hard, unaltered rocks can be seen to pass gradually upward into good, arable soil, three samples were selected for analysis, as follows: (I) Fresh gray granite, consisting of both potash and soda-lime feldspars, quartz, and black mica, with some epidote, apatite, white mica (sericite), black tourmaline, and iron oxides; (II) the same rock, where decomposed and brown, but still moderately firm; (III) the surface soil, on which vegetation was growing. Bulk analyses of each of these three types show that the transition from fresh rock to soil has involved only slight changes in ultimate chemical composition, consisting only in the addition of 3.5 per cent. of water, the change of the ferrous oxide to ferric, and a slight decrease in the total amounts of silica, lime, potash, and soda. It thus becomes evident that the alteration is chiefly a physical process. In the further investigation of the problem samples of the soil were treated for a period of ten days with (1) cold distilled water; (2) cold distilled water through which carbonic acid gas was kept bubbling; (3) acetic acid; and (4) hydrochloric acid of one fourth normal strength. The first two agents removed slight traces only of the more soluble constituents; the third, less than 0.1 per cent.; and the fourth, 3.6 per cent. (chiefly alumina and ferric oxide). Analyses from other localities are introduced for comparison, and it is shown that the decay of the granite, which is due to disintegration quite as much as to decomposition, has taken place wholly during post-Cretaceous time. The various causes of disintegration, physical and chemical, such as changes of temperature, oxidation, hydration, and solution, are examined, and hydration is found to be the most pronounced and universal. Hydration involves expansion, and, since the various minerals must expand unequally, disintegration results. The average amount of expansion involved in the passage of fresh granite to soil is found to be, approximately, 1.88.

W. O. CROSBY.

Composition of the Cleaned Ores of Lead and Zinc Produced at Aurora, Mo. By H. G. SPENCER. *Bull. Missouri Mining Club*, **1**, 28–33. — Complete analyses (with the exception of cadmium, arsenic, and lime) are given of the galena, calamine, and blende produced by the various mines in the vicinity of Aurora. Each analysis is accompanied by the average price paid for the ore which it represents, the primary object of the investigation being to secure uniform and reasonable prices for the producers.

W. O. CROSBY.

Analysis of Cretaceous Clays from Long Island. By C. H. JOÜET. *School Mines Quart.*, **16**, 149. — Complete analyses of three silicious clays from the Cretaceous beds in the vicinity of Northport and Sea Cliff, Long Island.

W. O. CROSBY.

The Costilla Meteorite. By R. C. HILLS. *Proc. Colorado Sci. Soc.*, Jan. 7, 1895. — A brief description of this meteorite, which was found in 1881 on Costilla Peak in Southern Colorado and weighs 78 pounds, is accompanied by an analysis showing: Fe, 91.65; Ni, 7.71; Co, 0.44; P, 0.10; S, 0.26. Total, 100.16. The sulphur and phosphorus are ascribed to troilite and schreibersite, both of which were observed on the etched surface.

W. O. CROSBY.

On the Origin of Gold Nuggets. By A. Liversidge. *Canadian Mining Review*, **13**, 251–252; **14**, 24–25. — The author summarizes the somewhat extensive literature of this subject and examines critically the numerous observations and experiments which have been supposed to lend support to theories of the origin of nuggets and placer gold. He then describes in detail a series of original experiments designed to test the general theory that nuggets grow in the placer deposits and are due in part or wholly to the chemical deposition of gold from percolating waters. Various sulphides (pyrite, galena, etc.) were found to precipitate gold from a solution of the double chloride of gold and sodium. Gold nuclei of various kinds, such as thin strips of chemically pure gold from the mint, nuggets and grains of placer gold, gold in quartz, etc., were immersed for periods of from 58 to 273 days in the gold chloride solution. More or less gold was usually precipitated, but it never became adherent to the nucleus, and the weight of the latter was usually slightly diminished and never increased. Various organic reducing agents were employed in these experiments, such as cork, paper, etc. Other experiments show that gold is also deposited when the nucleal mass is in contact not only with metalliferous sulphides and arsenides, which form strong galvanic couples, but also with such substances as iron oxides, charcoal, graphite, sandstone, granite, quartz, clay, and marble, which form but weak galvanic couples with the gold nucleus. The author follows several previous writers in attributing the higher average purity or fineness of placer as compared with vein gold to the solution by percolating waters of silver and other impurities, and it is shown that gold dust, exposing relatively more surface, is finer than nuggets. The general conclusion reached is that, while nuggets can undoubtedly be obtained artificially along the lines of his experiments, and gold is being chemically deposited in placers, the large nuggets of placers have not been formed in this way, although the finer grains and dust may have been appreciably thus enlarged.

W. O. Crosby.

Diabase Dykes in the Sudbury (Ontario) Region. By T. L. Walker. *Canadian Mining Review*, **14**, 25–26; 43–44. — These dikes form a series cutting the various members of the Huronian formation approximately at right angles. They vary in width from a few feet to 50 yards, and weather in spheroidal fashion to a deep brown earth. A detailed account of the microscopic features and contact phenomena is followed by a complete chemical analysis, and two analyses of the diabases of other regions are quoted for comparison. The distinguishing features of the Sudbury diabase are the large proportions of ferrous oxide and titanium. The titanium occurs partly in the augite, and gives it a violet color. Traces of nickel, cobalt, and copper, the metals whose ores are so extensively mined in the Sudbury district, were found, and also a trace of barium, which element, it is noted, is of much commoner occurrence in rocks than was formerly supposed. In referring to the nickel the author says that, although the proportion may seem to be trifling (.0275 per cent.), there is more nickel in one of these dikes than in the best nickel mine in the Sudbury region; but it is, of course, valueless from lack of concentration.

W. O. Crosby.

APPARATUS.

A New Form of Water-Oven and Still. BY HOFFMANN and HOCHSTETTER. *J. Am. Chem. Soc.*, 17, 122–124. — The apparatus consists of the usual form of water-oven, the heating surface of which is very largely increased by pipes through which the water circulates, similar to the water tube boilers. This provides perfect circulation, and the steam formed passes into a block tin worm and is condensed; the cooling water from this condenser passes into the oven free from sediment and almost at the boiling temperature. The arrangement makes steam in four minutes and furnishes thirteen and one half gallons in twenty-four hours with a Bunsen burner, using three feet of gas per hour. The exact arrangement is shown by a cut accompanying the article.

A. H. GILL.

Hydrogen Gas Apparatus for the United States' Signal Service. BY O. CHANUTE. *Am. Eng. R. R. J.*, 69, 46–47. — Sheet iron, lead-lined tanks of twelve, sixty, and seventy-two gallons' capacity are used for the sulphuric acid, water, and diluted acid, respectively. The acid runs into the bottom of the generator, an elongated lead-lined funnel 4 feet by 2 feet in diameter; this is fitted with a round, movable cover, provided with a 12-inch water seal, an overflow bowl, and a waste pipe for the spent acid. The hydrogen is washed with water, dried by quicklime, and passed into a 1,000 cubic foot gas holder. The larger parts of the apparatus are built of sheet iron No. 16 B. W. G., with riveted and calked joints; the smaller parts are of No. 14 B. W. G. iron; the lead used weighs six pounds to the square foot. The whole apparatus is so arranged that the parts fit one inside the other for convenience in transportation. It is used for making hydrogen for inflating balloons. It is connected with a specially constructed condensing pump, compressing 1000 cubic feet to 101 atmospheres in 101 minutes, or to 121 atmospheres in two hours.

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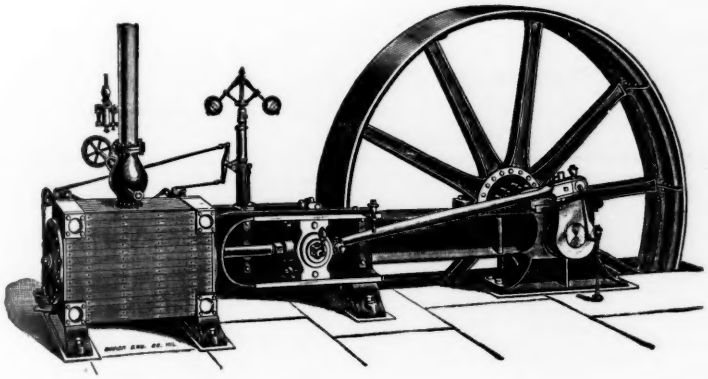

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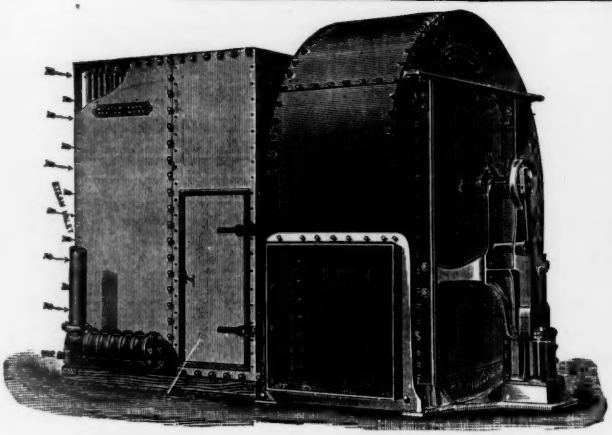

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